Klasse 21 a. **Ausgegeben am 25. August 1903.**

KAIS. KÖNIGL. PATENTAMT.

Österreichische

PATENTSCHRIFT Nr. 13115.

NIKOLA TESLA IN NEW-YORK (V. ST. v. A.).

Einrichtung zur Übertragung elektrischer Energie.

Angemeldet am 11. Juli 1901. — Beginn der Patentdauer: 1. April 1903.

Das den Gegenstand vorliegender Erfindung bildende Verfahren und die Einrichtung zur Ausführung desselben beruhen auf folgender, durch Versuche festgestellter Tatsache.

Wenn ein Stromleiter, der frei schwingen kann, bei einer niedrigen Temperatur erhalten wird, so werden die in demselben hervorgerufenen Schwingungen in erhöhtem Grade verstärkt und bezüglich der Zeitdauer verlängert. Diese Erscheinung wird für die vorliegende, für verschiedene Zwecke, jedoch hauptsächlich zur Übertragung elektrischer Energie mittels elektrischer Wellen geeignete Einrichtung in folgender Weise ausgenützt.

Die einfachste Anordnung bestände darin, daß der frei schwingbare, bei niedriger Temperatur zu erhaltende Stromleiter von einem geeigneten Kühlmittel beliebiger Art, wie z. B. flüssiger Luft, umgeben würde.

In umstehender Zeichnung ist ein derartiger Apparat einfachster Form schematisch und in perspektivischer Darstellung veranschaulicht.

Derselbe besteht aus zwei Vorrichtungen, von denen jeder als Sender, der jeweilig andere als Empfänger verwendet werden kann. Jede der beiden Vorrichtungen enthält eine mit wenigen Wicklungen versehene Spule A bezw. A' von geringem Widerstande. Die Spule A, welche als Teil des Übertragers angenommen werden soll, ist mit einer geeigneten Stromquelle zu verbinden, während die Spule A' in den Stromkreis des Empfängers eingeschaltet ist. Im Induktionsbereich zu diesen Spulen ist in jeder der beiden Vorrichtungen eine flach gewundene Drahtspirale B bezw. B' angeordnet, deren eines Ende durch die Platte C an die Erde gelegt ist, während das andere Ende von der Mitte der Spirale ausgehend an eine isolierte Klemme angeschlossen werden kann. Die Spulen B B^1 sind in aus Isoliermaterial bestehenden Behältern D eingesetzt, welche das Kühlmittel enthalten und um welche die Spulen A bezw. A' gewickelt sind.

Dem oben erwähnten zufolge treten nachstehende Begleiterscheinungen auf: Es sei zunächst der einfachste Fall angenommen, daß der Spule A des Senders unabhängig von ihren freien Schwingungen Stromimpulse oder Stromschwankungen (Stöße) beliebiger Zahl (Frequenz) aufgedrückt werden. In diesem Falle werden in der Spule B entsprechende Schwankungen induziert; ist die Spule B so eingerichtet, daß sie in gleichem Maße schwingt, so werden die induzierten Schwingungen bedeutend verstärkt. Die Verstärkung ist dem Produkt der Stromschwankungszahl (Frequenzzahl) und der Induktionsfähigkeit des Leiters B gerade und dem Widerstand des letzteren umgekehrt proportional und ist umso größer, je geringer die Dämpfung ist, und da die letztere mit der Verringerung des Widerstandes ebenfalls abnimmt, so wird unter sonst gleich bleibenden Bedingungen die Intensität der Schwingungen in dem zur Mitschwingung (Resonnanz) veranlaßten Leiter B im gleichen Verhältnis gesteigert, als der Widerstand derselben abnimmt.

Die Schwingungen der Spule B breiten sich im Raume aus und verursachen, sobald sie durch den Boden oder ein anderes leitendes Mittel den entsprechend abgestimmten Empfangsleiter B' erreichen, gleiche Schwingungen in demselben, welche aus den gleichen oben angegebenen Gründen verstärkt werden, wobei entsprechend stärkere Stromschwankungen oder Schwingungen in dem an die Empfangsstation angeschlossenen Leiter A' hervorgerufen bezw. induziert werden.

Wenn der Leiter A in willkürlichen Zeitabschnitten erregt wird, wie dies bei der Übertragung von Zeichen der Fall ist, so wird die Wirkung auf den Empfänger in der

oben angegebenen Weise verstärkt und zwar nicht allein, weil die Impulse in den Spulen *B* und *B'* gesteigert werden, sondern auch wegen der während eines längeren Zeitraumes andauernden Impulse, denn wenn der Leiter *A* unterbrochen wird, so dauern die in der Spule *B* erregten freien Schwingungen noch weiter und zwar wegen des geringen Widerstandes dieser Spule und der hiedurch bewirkten Verringerung der Dämpfung.

Die Kühlung des Leiters *B* hat also eine doppelte Wirkung. Sie vergrößert die Schwingungsweite und die Anzahl der in der Spule *B'* hervorgerufenen Schwingungen. Da die Amplitude der freien Schwingungen in der letzteren Spule proportional ist, der Amplitude und Zahl der Schwingungen in der Spule *B* und ferner die Kühlung der Spule *B'* die gleiche Wirkung hervorbringt, so wird die Intensität des Stromes im Leiter *A'* beträchtlich erhöht.

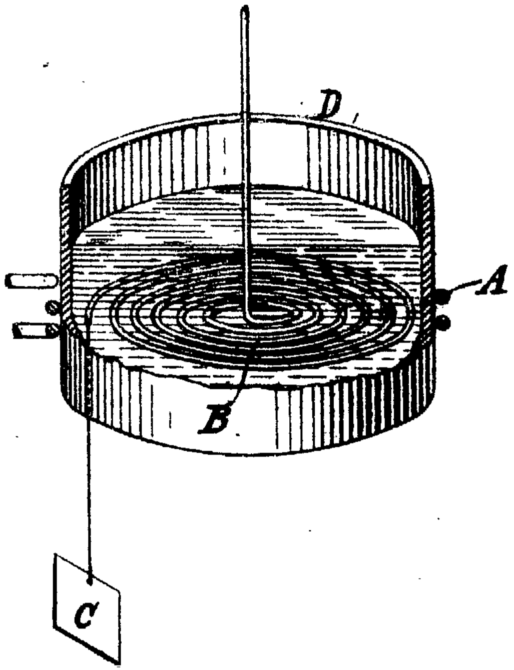
Die angegebenen Wirkungen werden noch erhöht, wenn der Leiter *A* des Senders, statt Impulse von willkürlicher Frequenz zu erhalten, mit der ihm eigenen Schwingungszahl oszillieren kann und diese Wirkungen sind noch größer, wenn der Leiter *A* durch die frei oszillierenden Entladungen hoher Frequenz eines Kondensators erregt wird.

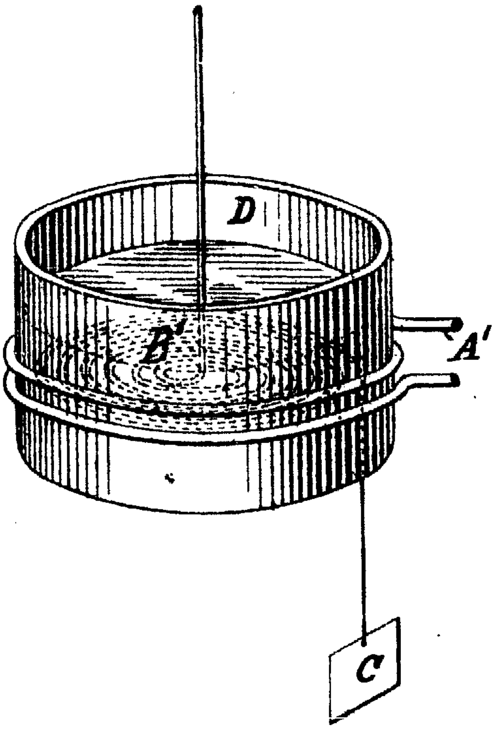
In diesem Falle wird durch Kühlung des Leiters *A* eine beträchtliche Verstärkung der im Empfänger hervorgerufenen Wirkungen erzielt.

Wenn der Leiter gekühlt und dessen Widerstand entsprechend verringert wird, so werden die Schwingungen stärker und länger andauernd ausfallen. Da die Schwingungen in den Spulen *B* und *B'* dem gleichen Gesetze unterliegen, so wird selbst durch sehr geringe Verminderung der Widerstände der beiden Spulen eine beträchtliche Steigerung der Wirkungen im Leiter *A'* erzielt. Übrigens kann der letztere, wenn erwünscht, auch abgestimmt und zu dem oben angegebenen Zwecke bei einer niedrigen Temperatur erhalten werden. In diesem Falle wird der durch die Erfindung erzielte Effekt relativ umso größer sein, je größer die Zahl der freischwingenden Leiter ist, welche abwechselnd und zwar einer von dem anderen Energie empfangen und abgeben.

PATENT-ANSPRUCH:

Einrichtung zur Übertragung elektrischer Energie mittels elektrischer Wellen, dadurch gekennzeichnet, daß die die elektrischen Schwingungen aussendenden oder aufnehmenden Leiter durch künstliche Mittel (verflüssigte Gase, Kältemischungen u. dgl.) auf einer niedrigen Temperatur gehalten sind, zum Zwecke, die Dämpfung der Schwingungen durch Verminderung des Widerstandes der Leiter zu verringern und demgemäß die Leistungsfähigkeit der Einrichtung bezüglich der Übertragung und Aufnahme von Schwingungen zu erhöhen.





Klasse 21 a. **Ausgegeben am 10. Juni 1904.**

KAIS. KÖNIGL. PATENTAMT.

Österreichische

PATENTSCHRIFT Nr. 16480.

NIKOLA TESLA IN NEW-YORK (V. ST. v. A.).

Einrichtung zur Übertragung elektrischer Energie.

Angemeldet am 26. Juli 1901. — Beginn der Patentdauer: 1. Februar 1904.

Man kennt bereits Verfahren und Vorrichtungen zur Erzeugung und Übertragung elektrischer Impulse oder Schwingungen durch die Luft, Erde, Wasser auf Empfangsvorrichtungen und zur Betätigung der letzteren für die Zeichengebung oder die Beherrschung anderer Vorrichtungen, die beliebiger Art und selbsttätig sein können.

Bei diesem Verfahren hat man die Empfangsvorrichtungen mit den Sendern abgestimmt, um sie noch empfindlicher für die von den letzteren erzeugten Impulse zu machen und sie den Einwirkungen von aus fremden Quellen stammenden Impulsen möglichst zu entziehen. Doch wird durch diese Anordnung nur eine beschränkte Geheimhaltung der zu übertragenden Impulse ermöglicht, weil es sehr schwierig ist, für solche Verfahren Vorrichtungen in irgendeiner erheblichen Anzahl zu bauen, welche ausschließlich auf Impulse oder Schwingungen einer bestimmten Art ansprechen.

Vorliegende Erfindung betrifft eine Einrichtung, um eine große Anzahl von Sende- und Empfangsstationen gleichzeitig gesondert und ausschließlich arbeiten zu lassen, ohne die Zeichen oder Nachrichten irgendeiner Störung, Unterbrechung oder Beeinflussung von fremder Seite her auszusetzen. Diese Einrichtung besteht in der Anordnung einer zwei oder mehrere Impulse oder Schwingungen verschiedener Länge erzeugenden Sendervorrichtung und einer in weiter Entfernung aufgestellten Empfangsvorrichtung mit zwei oder mehreren gesondert auf diese Impulse oder Schwingungen ansprechenden Abteilungen und einem Empfänger (Relais oder dgl.), der nur beim gleichzeitigen Zusammenarbeiten dieser Abteilungen in Tätigkeit tritt. Durch den Empfänger kann dann eine beliebige Arbeitsvorrichtung betätigt werden, z. B. eine Telegraphenvorrichtung, ein Semaphorarm, ein Uhrwerk, ein sich selbsttätig bewegendes Schiff u. s. w.

Zwar ist es an sich nicht neu, Ätherwellen von verschiedener Wellenlänge und gleicher Schwingungsebene zu verwenden; schon Jegou hat in den „Comptes Rendus“ darauf hingewiesen. Der Zweck jedoch, in dem die Verwendung solcher Wellen in Vorschlag gebracht wurde, ist ein durchaus anderer.

Impulse oder Schwingungen verschiedener Beschaffenheit zu erzeugen, ist ebensowenig neu. Man hat auch (vgl. amerikanische Patentschrift Nr. 663400) bereits vorgeschlagen, solche Schwingungen an der Empfangsstelle durch eine gleiche Anzahl Empfänger aufnehmen zu lassen, deren jeder nur auf eine bestimmte von diesen Schwingungen anspricht und wobei nur bei gleichzeitigem Ansprechen beider Empfangsvorrichtungen ein bestimmter Signalapparat in Tätigkeit tritt. Bei der vorliegenden Erfindung handelt es sich um eine Vorrichtung zur Nachrichtenübermittlung durch elektrische Wellen verschiedener Länge.

Fig. 1 und 2 auf der Zeichnung veranschaulichen schematisch die auf der Sendestation bezw. Empfangsstation benutzten Vorrichtungen und Stromkreise, Fig. 3, 4 und 5 betreffen andere Ausführungsformen, welche nach vorliegender Erfindung zur Anwendung kommen können.

In Fig. 1 sind zwei spiralig gewundene Spulen oder Leiter S^1 S^2 dargestellt, welche an ihren inneren Enden mit zweckmäßig in einer Höhe angeordneten Endplatten D^1 bezw. D^2 und an ihren äußeren Enden mit einer Erdplatte E verbunden sind. Die beiden

Spulen oder Leiter bezw. Stromkreise D^1 S^1 E und D^2 S^2 E haben verschiedene, passend gewählte Schwingungsperioden und solche Längen, daß die Punkte der in ihnen entwickelten höchsten Spannungen sich mit den erhöhten Endplatten D^1 D^2 decken. Unter passend gewählten Schwingungsperioden werden hier Perioden verstanden, welche die größte Sicherheit gegen voneinander oder von außen her kommende Störungen bieten. In dieser Hinsicht erhält man die günstigsten Ergebnisse, wenn die verschiedenen Perioden sich zueinander verhalten, wie die reziproken Werte der kleinsten Primzahlen. In jedem Falle, gleichviel ob diese Bedingung erfüllt wird oder nicht, sollten die Schwingungen so gewählt sein, daß sie beim Durchlaufen eines gemeinsamen Weges oder Stromkreises darin die größtmögliche Anzahl von Schwingungen erzeugen. Ferner sollten sie sich nicht so sehr der Art der Hertzschen Wellen nähern, weil mit solchen Schwingungen arbeitende Stromkreise wie D^1 S^1 E und D^2 S^2 E wegen der schnellen Ausstrahlung der Energie in den Raum sich als zu schwach erweisen. Den beiden Stromkreisen können elektrische Schwingungen in irgendeiner Weise mitgeteilt werden, zweckmäßig in der Art, daß man sie durch in ihrer Nähe angeordnete Primärleiter P^1 und P^2 erregt. Zweckmäßig werden einstellbare Widerstände L^1 L^2 in den Primärstromkreis eingeschaltet, hauptsächlich um die Art der Primärschwingungen zu regeln. In der Zeichnung umgeben die Primärleiter P^1 und P^2 die Spulen S^1 und S^2 und sind miteinander in Reihenschaltung durch die Widerstände L^1, L^2, Leiter F, Kondensatoren C^1 und C^2, Bürstenhalter B^1 und B^2 und die gezahnte Scheibe D verbunden. Die gezahnte Scheibe D ist mit dem Leiter F, gewünschtenfalls auch mit der Erdplatte E, wie veranschaulicht, verbunden. Auf diese Weise sind zwei unabhängige Primärstromkreise gebildet. Die Kondensatoren C^1 und C^2 haben eine solche Kapazität, und die Widerstände L^1 L^2 sind so eingeschaltet, daß jeder Primärstromkreis sich nahezu in Resonanz mit seinem Sekundärstromkreise befindet. Dabei muß darauf geachtet werden, daß jeder der Sekundärstromkreise D^1 S^1 E und D^2 S^2 E in seinem Grundton schwingt, da sonst die Vorrichtung nicht befriedigend arbeiten wird. Sind die Kapazitäten der Spulen S^1 und S^2 verhältnismäßig klein, so ergibt sich die richtige Abstimmung, wenn das Produkt aus Kapazität und Induktanz in jedem Primärstromkreise annähernd gleich dem Vierfachen desjenigen im zugehörigen Sekundärstromkreise ist. Die Bürstenhalter B^1 und B^2 lassen sich unabhängig voneinander im Winkel und wenn nötig, auch seitlich einstellen, so daß eine beliebige Aufeinanderfolge oder ein beliebiger Phasenunterschied zwischen den in den beiden Primärstromkreisen auftretenden Entladungen erreicht werden kann. Die Kondensatoren C^1 und C^2 werden von einer beliebigen Energiequelle S, zweckmäßig von hohem Potential, geladen. Die gezahnte Scheibe D wird in Umdrehung versetzt, so daß ihre Zähne oder Arme p p in aufeinander folgender Reihe in die nächste Nähe der leitenden Stangen oder Bürsten n n oder je nach den Umständen in Berührung mit denselben treten, wodurch die Kondensatoren in rascher Aufeinanderfolge durch ihre bezüglichen Stromkreise entladen werden. Dadurch werden die zwei Sekundärstromkreise D^1 S^1 E und D^2 S^2 E in Schwingungen versetzt, und zwar jeder in seiner eigenen Weise für einen bestimmten Zeitraum nach jeder Entladung. Die zwei verschieden langen Impulse oder Schwingungen werden durch die Erdplatte E der Erde mitgeteilt, breiten sich in derselben aus und erreichen die Empfangsstation. Die letztere ist mit zwei ähnlichen Stromkreisen e s^1 d^1 und e s^2 d^2 ausgerüstet, die in derselben Art, wie die Stromkreise der Senderstation angeordnet und mit denselben abgestimmt sind, so daß jeder von ihnen ausschließlich auf eine der zwei in der Senderstation erzeugten Schwingungen von verschiedener Länge anspricht. In der Empfangsstation werden dieselben Grundsätze wie in der Sendestation für die Einstellung der Teile der Stromkreise beobachtet. Dabei ist dafür zu sorgen, daß die Abstimmung stattfindet, wenn alle Teile der Stromkreise verbunden und richtig eingestellt sind, da jede Abweichung die Schwingungen mehr oder weniger abändern würde. Die Empfangsspulen s^1 und s^2 sind einzeln im Nebenschluß zu Stromkreisen geschaltet, die empfindliche Vorrichtungen a^1 bezw. a^2, Batterien b^1 bezw. b^2, einstellbare Widerstände r^1 bezw. r^2 und empfindliche Relais R^1 bezw. R^2 in Reihenschaltung enthalten, wie Fig. 2 veranschaulicht. Die Art der Verbindung und die Anordnung der verschiedenen Vorrichtungen ist großenteils nebensächlich und kann vielfach abgeändert werden. Die empfindlichen Vorrichtungen a^1 und a^2 können von einer beliebigen bekannten Art sein. Beispielsweise können sie jede aus zwei durch eine sehr dünne Schicht von Luft oder Dielektrikum getrennten leitenden Endstücken bestehen, die durch eine Batterie oder andere Energiequelle bis zur Durchschlagsentladungsgrenze gespannt sind, so daß sie bei der geringsten Störung nachgeben. Ihr ursprünglicher empfindlicher Zustand kann nach jeder Entladung durch Öffnen des Batteriestromes auf einen Augenblick oder in anderer Weise wieder hergestellt werden. Die Relais R^1 R^2 haben Anker l^1 l^2, welche untereinander durch einen Draht w verbunden sind und bei ihrer Anziehung durch Berührung mit den Kontakten c^1 und c^2 einen Stromkreis schließen, der eine Batterie b^3, einen einstellbaren Widerstand r^3

und ein als Empfänger dienendes Relais R^3 enthält. Es wird nun ersichtlich, daß das Relais R^3 nur dann in Tätigkeit tritt, wenn beide Kontakte c^1 und c^2 in Berührung mit ihren Ankern treten.

Das Aussenden der Schwingungen verschiedener Länge von der Sendestation kann in einer beliebigen Weise bewirkt werden, beispielsweise durch Öffnen und Schließen des Stromkreises der Energiequelle S, so daß beim jedesmaligen Schließen desselben zwei verschieden lange elektrische Schwingungen gleichzeitig oder in rascher Aufeinanderfolge je nach Belieben ausgesandt werden. Die zwei Empfangsstromkreise der Empfangsstation, welche einzeln auf die von den ihnen entsprechenden Stromkreisen der Sendestation erzeugten Schwingungen ansprechen, betätigen durch die empfindlichen Vorrichtungen a^1 und a^2 die Relais R^1 und R^2, deren Anker durch die Kontakte c^1 und c^2 ihren Stromkreis schließen und so das als Empfänger dienende Relais R^3 in Tätigkeit setzen. Das Letztere zieht seinen Anker an, der durch Berührung mit dem Kontakte c^3 den Stromkreis der Batterie b^4 schließt und dadurch eine Arbeitsvorrichtung a^3 in Tätigkeit setzt. Wird aber durch eine fremde Störung einer der beiden Empfangsstromkreise in seiner Wirkung beeinträchtigt, so kann natürlich auch das Relais R^3 nicht in Tätigkeit treten. Auf diese Weise kann beispielsweise eine Nachrichtenübertragung mit erhöhter Sicherheit gegen fremde Einmischung bewirkt, folglich auch die Geheimhaltung der Botschaft gesichert werden. Die in Fig. 2 veranschaulichte Empfangsstation vermag keine Nachricht nach der Sendestation zu geben. Sollten aber beide Stationen Nachrichten sowohl aussenden als auch empfangen können, so müssen sie gleich eingerichtet sein. Es kann dann irgendeine Anordnung, die hier nicht näher dargestellt zu sein braucht, getroffen werden, um die Vorrichtung auf jeder Station, sowohl als Sender als auch als Empfänger benutzen zu können.

Die Endplatten D^1 und D^2 der Sendevorrichtung und diejenigen d^1 d^2 der Empfangsvorrichtung sind in der Zeichnung als voneinander isoliert dargestellt. Jedoch ist dies, obwohl vorteilhaft, nicht durchaus notwendig. Die zwei Platten können untereinander verbunden sein oder es kann nur eine einzige Endplatte D^1 bezw. d^1 auf jeder Station benutzt werden.

Die Betätigung eines Empfängers, wie R^3, kann ferner statt von zwei Sendestromkreisen, wie oben beschrieben, von mehreren Sendestromkreisen abhängig gemacht werden, so daß auf diese Weise ein beliebiger Grad von Sicherheit und Geheimhaltung der Nachricht gegen fremde Einrichtungen erreichbar ist.

Die in Fig. 1 und 2 veranschaulichten Vorrichtungen ermöglichen auch verschiedene Wirkungen durch Einstellung der Aufeinanderfolge oder des Phasenunterschiedes der Entladungen in den Primärstromkreisen P^1 und P^2. Beispielsweise kann die Wirkung der Relais R^1 R^2 entweder durch Änderung der Gewichte der Anker l^1 l^2 oder der Stärke der Batterie b^1 b^2 oder durch Einstellung der Widerstände r^1 r^2 oder in anderer Weise geregelt werden, so daß, wenn auf der Sendestation eine bestimmte Aufeinanderfolge oder Phasendifferenz der Entladungen in den Primärstromkreisen P^1 und P^2 stattfindet, die Anker l^1 und l^2 zu gleicher Zeit durch die Kontakte c^1 c^2 ihre Stromkreise schließen und so das Relais R^3 betätigen, dagegen ihre Dienste versagen, wenn die Aufeinanderfolge oder Phasendifferenz geändert ist. Durch diese oder ähnliche Mittel kann eine vermehrte Sicherheit gegen fremde Störungen erreicht werden, außerdem auch noch die Möglichkeit, die Zeichengebung durch Änderung der Aufeinanderfolge der Entladungen in den zwei Primärstromkreisen noch geheimer zu gestalten. Anstatt in oben angegebener Weise den Stromkreis der Quelle S für die Aussendung verschieden langer Impulse oder Schwingungen zu schließen und zu öffnen, kann es zweckmäßig sein, nur die Periode in jedem Sendestromkreise in irgendeiner bekannten Weise willkürlich zu ändern, beispielsweise durch Einstellung der Widerstände in den Primärstromkreisen. Hinsichtlich der in Fig. 2 veranschaulichten Vorrichtung ist noch zu bemerken, daß bestimmte Wirkungen durch Parallelschaltung der Kontakte c^1 und c^2, anstatt durch Reihenschaltung, wie dargestellt, erreichbar sind. In diesem Falle muß natürlich das Relais R^3 so eingerichtet oder eingestellt sein, daß es nur dann in Tätigkeit tritt, wenn beide Kontakte geschlossen sind.

Es ist nicht nötig, Sendevorrichtungen mit zwei oder mehreren gesonderten Teilen, wie S^1 und S^2 oder Stromkreisen zu verwenden, da eine Aufeinanderfolge von Impulsen oder Schwingungen verschiedener Länge auch durch eine Vorrichtung mit einem einzigen Stromkreise erzeugt werden kann. Einige Vorrichtungen dieser Art sind beispielsweise in Fig. 3, 4 und 5 dargestellt. In Fig. 3 ist eine Sendevorrichtung e s^3 d^3 teilweise im Nebenschluß zu einer umlaufenden Scheibe D^3 geschaltet, welche ähnlich wie die in Fig. 1 dargestellte eingerichtet sein kann. Diese Scheibe schaltet zeitweise einen Teil der Spule s^3 aus oder verbindet ihn, wenn gewünscht, durch einen einstellbaren Kondensator C^3, wodurch die Schwingung des Stromkreises $e\ s^3\ d^3$ zu passenden Zeitpunkten geändert wird, so daß zwei Impulse oder Schwingungen verschiedener Länge in rascher Aufeinanderfolge ausgesandt werden. Eine ähnliche Wirkung wird von dem in Fig. 4 veranschaulichten Stromkreise $e\ s^4\ d^4$ erzeugt durch zeitweise eintretenden Kurzschluß einer Sekundärleitung p^4 unter Vermittlung einer Induktionsrolle L^3 und einer umlaufenden Scheibe D^4 mit isolierenden und leitenden Segmenten oder in anderer Weise. Von der in Fig. 5 dargestellten Vorrichtung $e\ s^5\ d^5$ werden drei verschieden lange Schwingungen ausgesandt, dadurch, daß zeitweise eine wechselnde Zahl Windungen einer Induktionsrolle L^4 durch eine umlaufende Scheibe D^5 mit zwei Vorsprüngen $p^5\ p^5$ und durch drei unter 120° voneinander abstehende Bürsten n^5 in Reihe mit dem schwingenden Stromkreise geschaltet wird. In jedem dieser drei Fälle kann die Empfangsstation mit zwei bezw. drei Stromkreisen ähnlich wie in Fig. 2 ausgerüstet sein, wobei selbstverständlich die vom Sender ausgehenden verschiedenen Schwingungen so rasch aufeinander folgen, daß sie wie gleichzeitig auftretende Schwingungen derselben Länge die Betätigung der Relais R^1 und R^2 oder dgl. bewirken. Es ist auch nicht notwendig, auf der Empfangsstation zwei oder mehrere Stromkreise, wie s^1 und s^2 anzuwenden, sondern es können auch einfache Stromkreise, wie die in Fig. 3, 4 und 5 dargestellten benutzt werden. In diesem Falle müssen die entsprechenden Scheiben wie D^3, D^4 und D^5 auf der Sendestation und der Empfangsstation übereinstimmend laufen.

Natürlich können die Sendevorrichtungen und Empfangsvorrichtungen eine größere Anzahl verschiedener Einzelvorrichtungen erhalten, welche in jeder möglichen Weise angeordnet und miteinander verbunden sein können. Dadurch wird die Möglichkeit geboten, von einer praktisch unbegrenzten Anzahl von Vorrichtungen eine einzelne zur Betätigung mittels, einen gemeinsamen natürlichen Weg (Luft, Erde, Wasser) oder eine gemeinsame künstliche Leitung (Drähte, Kabel) durchlaufender Impulse oder Schwingungen auszuwählen, also jeder Vorrichtung ein besonderes Kennzeichen zu erteilen und sie gegen unbefugte Benutzung oder fremde Einmischung durchaus zu schützen, so daß sie mit voller Sicherheit angerufen werden kann, ohne eine Verwechslung mit zahllosen anderen Vorrichtungen befürchten zu müssen.

Die Erfindung läßt sich, wie aus obigem ersichtlich ist, nicht nur auf die besondere, hier beschriebene Übertragung von Impulsen oder Schwingungen durch die natürlichen Wege (Luft, Erde, Wasser u. s. w.) anwenden, sondern auch auf andere Verfahren zur Übertragung elektrischer Impulse oder Schwingungen durch Drähte oder Kabel für die Betätigung von telegraphischen oder telephonischen oder anderen von der Sendevorrichtung weit entfernten Arbeitsvorrichtungen.

PATENT-ANSPRÜCHE:

1. Einrichtung zur sicheren Betätigung eines bestimmten Empfängers mittels elektrischer Impulse oder Schwingungen verschiedener Beschaffenheit, dadurch gekennzeichnet, daß auf der Sendestation eine Anzahl Arten von Impulsen oder Schwingungen verschiedener Beschaffenheit erzeugt und ausgesandt werden und daß auf der Empfangsstation eine gleiche Anzahl von Schwingungssystemen in Anwendung kommen, die einzeln nur auf Impulse oder Schwingungen je einer Beschaffenheit ansprechen und nur beim gleichzeitigen Zusammenarbeiten einen Empfänger betätigen.

2. Bei einer Schaltungseinrichtung nach Anspruch 1 eine Übertragungsvorrichtung, dadurch gekennzeichnet, daß dieselbe durch rasch aufeinander folgendes Schließen und Öffnen einer Anzahl verschieden abgestimmter Schwingungssysteme oder durch rasch wechselnde Änderung der Schaltung eines oder mehrerer Schwingungssysteme eine Anzahl praktisch gleichzeitig auftretender Impulse oder Schwingungen von verschiedener Länge erzeugt.

Hiezu 1 Blatt Zeichnungen.

Druck von R. Spies & Co., Wien.

NIKOLA TESLA in NEW-YORK (V. ST. v. A.).

Einrichtung zur Übertragung elektrischer Energie.

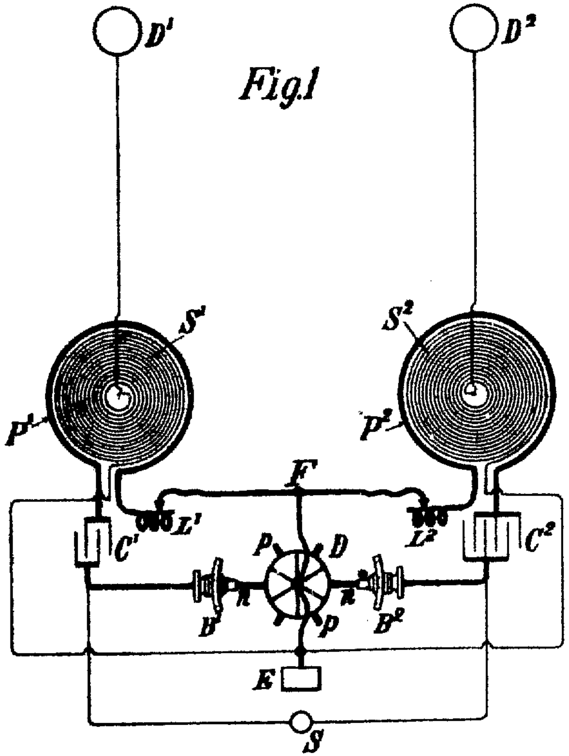


Fig.1

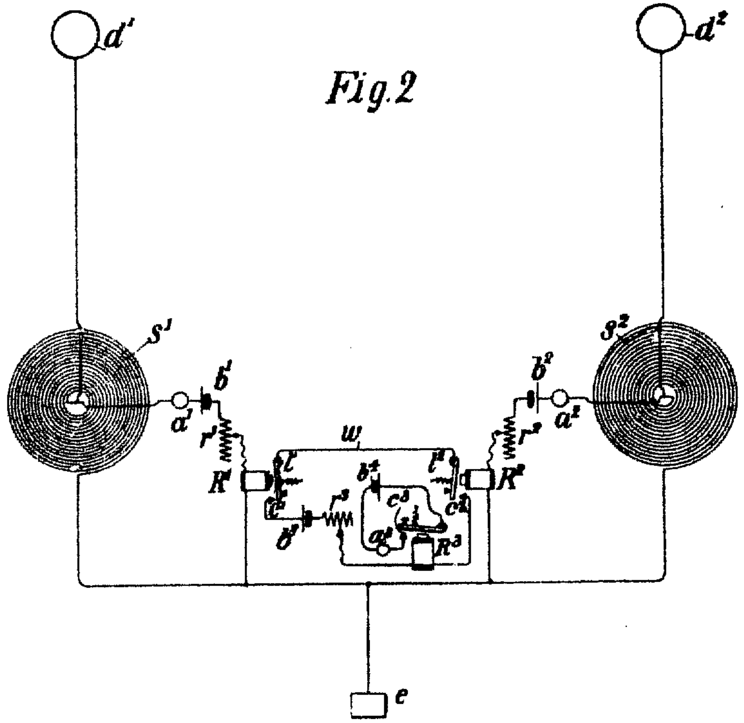


Fig.2

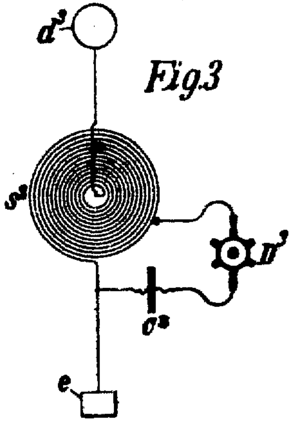


Fig.3

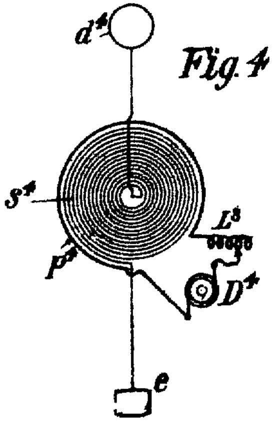


Fig.4

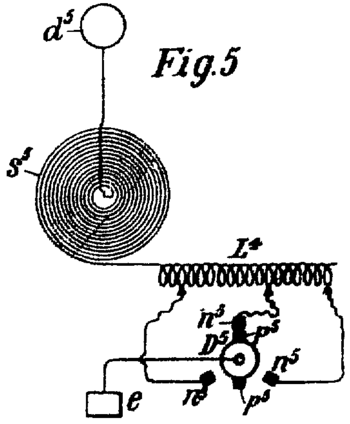


Fig.5

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(71) Applicant: **TESLA NIKOLA (US)**

(72) Inventor: **TESLA NIKOLA (US)**

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(54) **ELECTRIC ARC LAMP**

(54) **LAMPE ELECTRIQUE A ARC**

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TO ALL WHOM IT MAY CONCERN:-

Be it known that I, Nikola Tesla, formerly of Smiljan Lika Border country of Austro-Hungary, now residing at Rahway, in the County of Union and State of New Jersey, United States of America Electrician, have invented certain Improvements in Electric Arc Lamps of which the following is a specification.

My invention relates more particularly to those arc lamps in which the separation and feed of the carbon electrodes, or their equivalents, is accomplished by means of electro-magnets or solenoids in connection with suitable clutch mechanism and it is designed to remedy certain faults common to the greater part of the lamps heretofore made. The objects of my invention are to prevent the frequent vibrations of the movable electrode and flickering of the light arising therefrom, to prevent the electrodes falling into contact, to dispense with the dash pot, clockwork or gearing and similar devices heretofore used and to render the lamp extremely sensitive and to feed the carbon almost imperceptibly, and thereby obtain a very steady and uniform light.

In my present invention I further provide means for automatically withdrawing a lamp from the circuit, or cutting out the same, when, from a failure of the feed the arc reaches an abnormal length, and also means for automatically reinserting such lamp in the circuit when the rod drops and the carbons come into contact.

No 6

My invention will be understood with reference to the accompanying drawings, in which

Fig. 1 is an elevation of the lamp with the case in section.

Fig. 2 is a sectional plan at the line x^2x^2.

Fig. 3 is an elevation of the lamp partly in section at right angles to Fig. 1.

Fig. 4 is a sectional plan at the line y y, Fig. 1.

Fig. 5 is a section of the clamp in about full size.

Fig. 6 is a detached section illustrating the connection of the spring to the lever that carries the pivots of the clamp, and

Fig. 7 is a diagram showing the circuit connections of the lamp.

M. represents the main, and N the shunt magnet, both securely fastened to the base A which with its side column S. S. is preferably cast in one piece of brass or other diamagnetic material. To the magnets are soldered or otherwise fastened the brass washers or disks a, a, a, a. Similar washers b, b, of fibre or other insulating material serve to insulate the wires from the brass washers.

The magnets M and N are made very flat so that their width exceeds three times their thickness, or even more. In this way a comparatively small number of convolutions is sufficient to produce the required magnetism; besides a greater surface is offered for cooling off the wires.

The upper pole pieces m, n, of the magnets are curved as indicated in the drawing Fig. 1; the lower pole pieces m', n', are brought near together tapering towards the armature g, as shown in Figs. 2 and 4. The object of this taper is to concentrate the greatest amount of the developed magnetism upon the armature and also to allow the pull to be exerted always upon the middle of the armature g. This armature g, is a piece of iron in the shape of a hollow cylinder having on each side a segment cut away, the width of which is equal to the width of the pole pieces m', n'.

The armature is soldered or otherwise fastened to the clamp r, which is formed of a brass tube provided with gripping jaws e, e, Fig. 5. These jaws are arcs of a circle of the diameter of the rod R, and are made of some hard metal, preferably of hardened German silver. I also makes the guides f, f, through which the carbon holding rod R, slides, of the same material. This has the advantage to reduce greatly the wear and corrosion of the parts coming in frictional contact with the rod which frepuently causes trouble. The jaws e, e, are fastened to the inside of the tube r, so that one is a little lower than the other. The object of this is to provide a greater opening for the passage of the rod when the same is released by the clamp.

The clamp r, is supported on bearings w, w, Figs. 1, 3 & 5, which are just in the middle between the jaws e, e, I find this disposition to be the best. The bearings w, w, are carried by a lever t, one end of which rests upon an adjustable support q, of the side columns S, the other end being connected by means of the link e-′ to the armature lever L.

The armature lever L is a flat piece of iron in Z shape having its ends curved so as to correspond to the form of the upper pole pieces of the magnets M and N. It is hung upon the pivots v, v, Fig. 2, which are in the jaw x, of the top plate B. This plate B, with the jaw is preferably cast in one piece and screwed to the side columns S. S. that extend up from the base A.

To partly balance the overweight of the moving parts a spring s,′ Figs. 2 and 6, is fastened to the top plate B, and hooked to the lever t. The hook e, is towards one side of the lever or bent a little sideways, as seen in Fig. 6. By this means a slight tendency is given to swing the armature towards the pole piece m′, of the main magnet.

The binding posts K, K′, are preferably screwed to the base A. A manual switch for short-circuiting the lamp when the carbons are renewed is also to be fastened to the base. This switch is of ordinary character and is not shown in the drawing.

The rod R, is electrically connected to the lamp frame by means of a flexible conductor or otherwise. The lamp case receives a removable ornamental cover s-2 around the same to enclose the parts.

86.

The electrical connections are as indicated diagrammatically in Fig. 7.

The wire in the main magnet consists of two parts x' and p'. These two parts may be in two separated coils or in one single helix as shown in the drawing. The part x-1 being normally in circuit is with the fine wire upon the shunt magnet wound and traversed by the current in the same direction so as to tend to produce similar poles N. N. or S. S. on the corresponding pole pieces of the magnets M and N. The part p' is only in circuit when the lamp is cut out, and then the current being in the opposite direction produces in the main magnet, magnetism of the opposite polarity.

The operation is as follows: At the start the carbons are to be in contact and the current passes from the positive binding post K to the lamp frame, carbon-holder, upper and lower carbon, insulated return wire in one of the side rods and from there through the part x' of the wire on the main magnet to the negative binding post. Upon the passage of the current the main magnet is energized and attracts the clamping armature g, swinging the clamp and gripping the rod by means of the gripping jaws e, e. At the same time the armature lever L is pulled down and the carbon separated. In pulling down the armature lever L the main magnet is assisted by the shunt magnet N, the latter being magnetized by magnetic induction from the magnet M.

It will be seen that the armatures L and g are practically the keepers for the magnets M and N and owing to this fact both magnets with either one of the armatures

L and g may be considered as one horseshoe magnet which we might term a compound magnet. The whole of the soft iron parts m, m′ g, n, n′ and L form a compound magnet.

The carbons being separated, the fine wire receives a portion of the current. Now the magnetic induction from the magnet M is such as to produce opposite poles on the corresponding ends of the magnet N, but the current traversing the helices tends to produce similar poles on the corresponding ends of both magnets and therefore, as soon as the fine wire is traversed by sufficient current, the magnetism of the whole compound magnet is diminished.

With regard to the armature g and the operation of the lamp, the pole m′ may be termed as the clamping and the pole n′ as the releasing pole.

As the carbons burn away the fine wire receives more current and the magnetism diminishes in proportion. This causes the armature lever L to swing and the armature g to descend gradually under the weight of the moving parts until the end p, Fig. 1, strikes a step on the top-plate B. The adjustment is such that when this takes place the rod R is yet gripped securely by the jaws e, e. The further downward movement of the armature lever being prevented, the arc becomes longer as the carbons are consumed and the compound magnet is weakened more and more until the clamping armature g releases the hold of the gripping jaws e, e, upon the rod R and the rod is allowed to drop a little, shortening thus the arc. The fine wire now receiving less current the magnetism increases and the rod is clamped again and slightly raised if necessary. This clamping and releasing of the rod continues until the carbons are consumed. In practice the feed is so sensitive that for the greatest part of the time the movement of the rod cannot be detected without some actual measurement. During the norman operation of the lamp the armature lever L remains stationary or nearly so in the position shown in Fig. 1.

Should it arise that owing to an imperfection in the rod the same and the carbons drop too far so as to make the arc too short or even bring the carbons in contact, then a very small amount of current passes through the fine wire and the compound magnet becomes sufficiently strong to act, as on the start, in pulling the armature lever L down and separating the carbons to a greater distance.

It occurs often in practice that the rod sticks in the guides. In this case the arc reaches a great length until it finally breaks; then the light goes out and frequently the fine wire is injured. To prevent such an accident, I provide my lamp with an automatic cut-out. This cut-out operates as follows:- When upon a failure of the feed the arc reaches a certain predetermined length, such an amount of current is diverted through the fine wire that the polarity of the compound magnet is reversed. The clamping armature g is now moved against the shunt magnet N until it strikes the releasing pole n'.

As soon as the contact is established the current passes from the positive binding post over the clamp r, armature g, insulated shunt magnet and the helix p' upon the main magnet M to the negative binding post. In this case the current passes in the opposite direction and changes the polarity of the magnet M, at the same time maintaining, by magnetic induction, in the core of shunt magnet, the required magnetism without reversal of polarity and the armature g remains against the shunt magnet pole n'. The lamp is thus cut out as long as the carbons are separated.

The cut out may be used in this form without any further improvement, but I prefer to arrange it so that if the rod drops and the carbons come in contact, the arc is started again. For this purpose I proportion the resistance of the part p' and the number of the convolutions of the wire upon the main magnet so that when the carbons come in contact, a sufficient amount of current is diverted through the carbons and the part x' to destroy or neutralize the magnetism of the compound magnet. Then the armature g having a slight tendency to approach to the clamping pole m' comes out of contact with the releasing pole n'. As soon as this happens the current through the part p' is interrupted and the whole current passes through the part x'. The magnet M is now strongly magnetized, the armature g is attracted and the rod clamped at the same time the armature lever L is pulled down out of its normal position and the arc started.

In this way the lamp cuts itself out automatically when the arc gets so long and reinserts itself automatically in the circuit if the carbons drop together.

It will be seen that the cut out may be modified without departing from the spirit of my invention as long as the shunt magnet closes a circuit including a wire upon the main magnet, and continues to keep the contact closed being magnetized by magnetic induction from the main magnet. It is also obvious to say that the magnets and armatures may be,of any desired shape.

I CLAIM AS MY INVENTION:-

1st. The combination in an arc lamp, of a main and a shunt magnet, an armature lever to draw the arc, a clamp and an armature to act upon the clamp, a clamping pole and a releasing pole upon the respective cores, the cores, poles armature lever and clamping armature forming a compound magnet, substantially as set forth.

2nd. The combination in an electric arc lamp, of a carbon holder and its rod, a clamp for such carbon holder, a clamping armature connected to the clamp, a compound electro magnet controlling the action of the clamping armature and electric circuit connections, substantially as set forth for lessening the magnetism of the compound magnet when the arc between the carbons lengthens and augmenting the magnetism of the same when the arc is shortened, substantially as described.

3rd. The combination with the carbon holders in an electric lamp, of a clamp around the rod of the upper car holder, the clamping armature connected with said clamp, the armature lever and connection from the same to the cl the main and shunt magnets and the respective poles of th same to act upon the clamping armature and armature lever respectively, substantially as set forth.

4th. In an electric arc lamp, a cut-out consisting of a main magnet, an armature, and a shunt magnet having an insulated pole piece, and the cut-out circuit connections through the pole piece and armature, substantially as set forth.

5th. In an electric arc lamp, the combination with the carbon holder and magnets, of the armatures L and g, link e′ clamp r and lever t and the spring s′ for the purposes set forth.

6th. In an electric arc lamp, the combination with two upright magnets in the main and shunt circuit respectively, having curved pole pieces on one end and converging pole pieces on the other end, of a flat z shaped armature lever between the curved pole piece and a clamping armature between the convergent pole pieces, substantially as described.

7th. The combination in an electric arc lamp, of an electromagnet in the main circuit and an electro magnet in the shunt circuit, an armature under the influence of the poles of the respective magnets and circuit connections controlled by such armature to cut out or shunt the lamp, substantially as specified, whereby the branch circuit is closed by the magnetism of the shunt magnet and then kept closed by induced magnetism from the main magnet, substantially as set forth.

C.C.

8th. The combination with the carbon holder and rod and the main and shunt magnets, of a feeding clamp, an armature for the same, clamping and releasing poles upon the cores of the respective magnets and circuit connections through the clamping armature, substantially as specified, for shunting the current when the arc between the carbons becomes abnormally long, substantially as set forth.

9th. The combination with the carbon holding rod and a clamp for the same, of an armature upon the clamp, a shunt magnet, the pole of which acts to release the clamp, a main magnet with a two part helix, one portion being in the main circuit and the other portion in a shunt or cut out circuit, the clamping armature acting to close said cut out circuit when the arc becomes too long, and to break the shunt circuit when the carbons come together, substantially as set forth.

10th. The combination with the carbon holders of two magnets, one in the main circuit and the other in a shunt circuit, and an armature lever to draw the arc, and a feeding mechanism and pole pieces upon the electro magnets, to act upon the feeding mechanism, substantially as specified.

11th. The combination with the carbon holders, of two magnets, one in the main circuit and the other in a

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shunt circuit, an armature lever between two poles of such electro magnets to draw the arc, pole pieces upon the other two poles of the electro magnets, and a feeding mechanism between and acted upon by such pole pieces substantially as specified.

12th. The combination with the carbon holder, of a tubular clamp surrounding the same, an armature lever connected to ~~said tubular~~ clamp and electro magnets in the main and shunt circuits respectively, and an armature upon the tubular clamp adjacent to ~~the~~ lateral poles of the electro magnets, substantially as set forth.

N. T.

New York N. Y.
Jan. 16. 1886
Signed in the presence of
Chs. H. Smith
Geo. T. Pinckney

Nikola Tesla

B. C.

Impts. in Electric Arc Lamps

24348

References.

A	Base
a	Washers
b	"
B	Top plate
f,	Guide
e'	Link
G	Armature
L	" Lever
M	Main Magnet
m	Pole piece
m'	" "
N	Shunt magnet
n	Pole Piece
n'	" "
o	Hook
p	Part of L
q	Support
R	Rod
s	Columns
s'	Spring
S²	Cover
t	Lever
v	Pivots
w	Bearings
x	Jaw

Fig. 1.

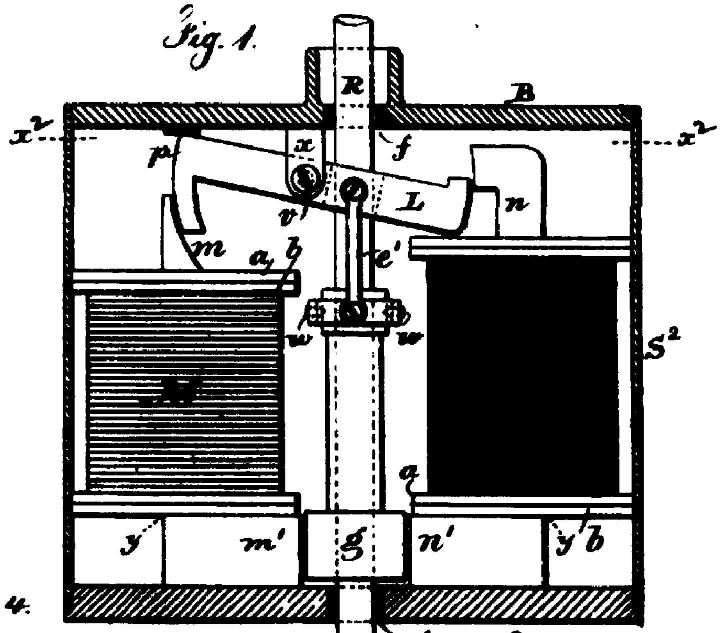


Fig. 4.

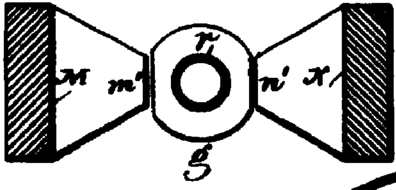
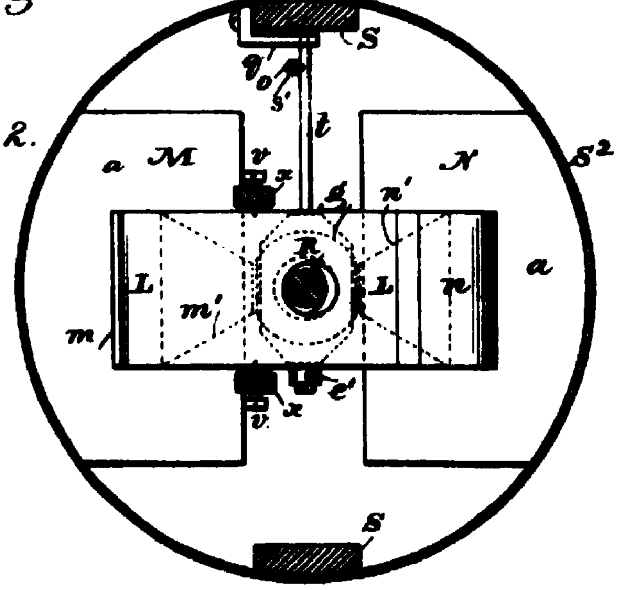


Fig. 2.



New York N.Y. Jan 18. 1886

Certified to be the drawings referred to in the specification hereunto annexed

Nikola Tesla
Inventor

per Lemuel W. Serrell
atty

Witnesses

Chas H. Smith

Wallace L. Serrell.

B

Impts. in Electric Lamps.

24348

Referenes

A. Base
a Washers
b "
e Gripping Jaws
e' Link
f Guide
G Armature
K Binding screw
K' " "
L Armature lever
M Main Magnet
m' Pole Piece
n' " "
o Hook
R Rod
r Clamp
q Support
S Columns
S' Spring
S² Cover
t Lever
v Pivots
w Bearings
x Jaw
N Shunt Magnet
m. Pole Piece
x' Part of Magnet M
p' " " "
B Top Plate
p. Part of L

Fig. 3.

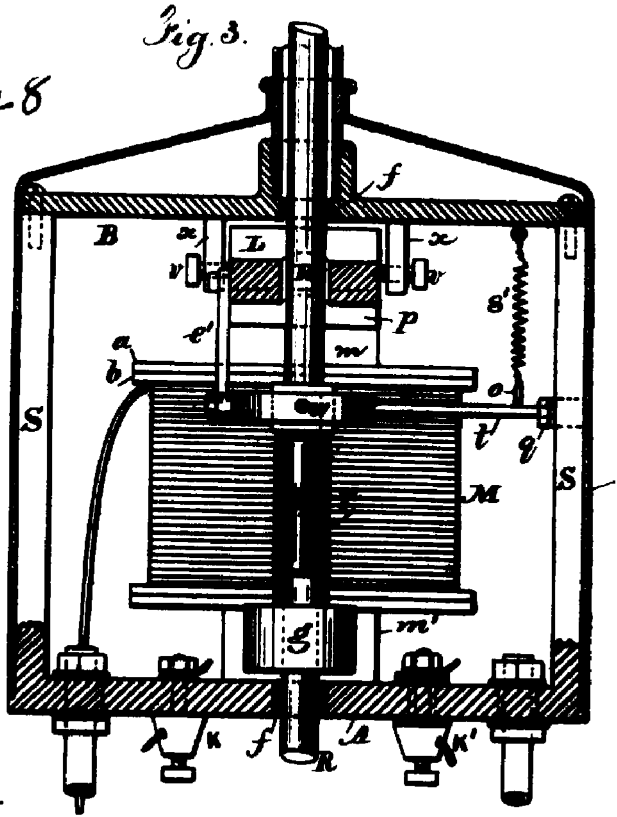


Fig. 6.

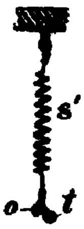


Fig. 5.

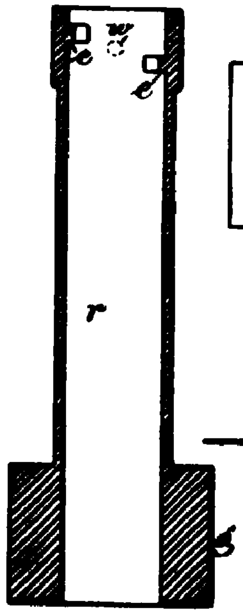
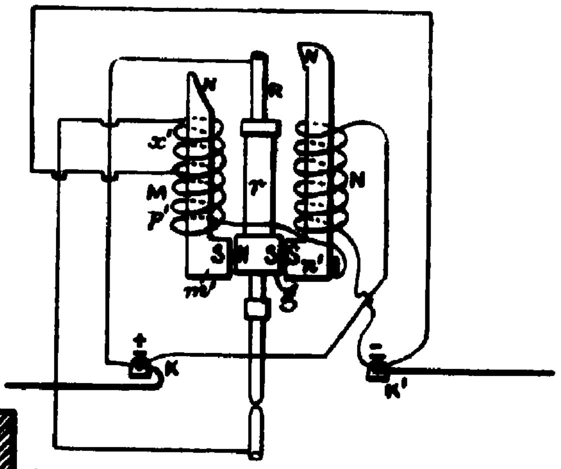


Fig. 7.



New York N.Y. Jan. 18. 1886
Certified to be the drawings referred to in the specification hereunto annexed

Witnesses
Chas H. Smith
Wallace L. Serrell

Nikola Tesla
Inventor
for Lemuel W. Serrell
atty

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(71) Applicant: **TESLA NIKOLA (US)**
(72) Inventor: **TESLA NIKOLA (US)**

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(54) **METHOD AND APPARATUS FOR CONVERTING ALTERNATING INTO DIRECT CURRENTS**
(54) **MODE ET APPAREIL DE CONVERSION DES COURANTS ALTERNATIFS EN COURANTS DIRECTS**

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SPECIFICATION.

TO ALL WHOM IT MAY CONCERN:-

BE IT KNOWN, THAT I, NIKOLA TESLA, from Smiljan, Lika, Border Country of Austria Hungary, resident of New York, in the County and State of New York, Electrician, have invented certain new and useful Improvements in methods and apparatus for Converting Alternating into Direct Currents, and I do hereby declare that the following is a full, clear, and exact description of the same.

In nearly all the more important industrial applications of electricity, the current is produced by dynamo-electric machines driven by power, in the coils of which the currents developed are primarily in reverse directions or what is known as alternating. As many electrical devices and systems, however, require direct current, it has been usual to correct the current alternations by means of a commutator instead of taking them off directly from the generating coils.

The superiority of alternating current machines in all cases where their currents can be used to advantage, renders their employment very desirable, as they may be much more economically constructed and operated and the object of this invention is to provide means for directing or converting at will at one or more points in a circuit, alternating into direct currents.

Stated broadly, the invention consists in obtaining direct from alternating currents, or in directing the waves of an alternating current so as to produce direct or substantially direct currents, by developing or producing in the branches of the circuit including a source of alternating currents, either permanently or periodically, and by electric, electro-magnetic, or magnetic agencies, manifestations of energy or what may be termed active resistances of opposite eectrical character whereby the currents or current waves of opposite sign or direction will be diverted through different circuits, those of one sign passing over one branch and those of opposite sign over another.

The case of a circuit divided into two paths only may be considered herein inasmuch as any further subdivision involves merely an extension of the same general principle.

Selecting then, any circuit through which is flowing an alternating current, let such circuit be divided at any desired point into two branches or paths. In one of these paths is inserted some device to create an electro-motive force opposed to the waves or impulses of current of one sign, and a similar device in the other branch which opposes the waves of opposite signs.

Assume, for example, that these devices are batteries, primary or secondary, or continuous current dynamo machines. The waves or impulses of opposite direction, composing the main current, have a natural tendency to divide between the two branches, but by reason of the opposite electrical character or effect of the two branches, one will offer an easy passage to a current of a certain direction, while the other will offer a relatively high resistance to the passage of the same current. The result of this distribution is that the waves of current of one sign will - partly or wholly - pass over one of the paths or branches while those of the opposite sign pass over the other.

There may be thus obtained from an alernating current two or more direct currents, without the employment of any commutator such as it has been heretofore regarded as necessary to use. The current in either branch may be used in the same way and for the same purposes as any other direct current, that is, it may be made to charge secondary batteries, energize electro-magnets, or used for any other analagous purpose.

In the drawings some of the various ways in which this invention may be carried out are illustrated.

The several figures are diagrammatic in characte and will be described in detail in their order.

Figure 1 represents a plan of directing the alt nating currents by means of devices purely electrical in character. A designates a generator of alternating currents and B, B, the main or line circuit therefrom.

At any given point in this circuit at or near which it is desired to obtain direct currents, the circuit B is divided into two paths or branches C, D. In each of these branches is placed an electrical generator which for the present may be assumed to produce direct or continuous currents.

The direction of the current thus produced is opposite in one branch to that of the current in the other branch, or considering the two branches, as forming a closed circuit, the generators E, F, are connected up in series therein, one generator in each part or half of the circuit.

The electromotive force of the current sources E and F may be equal to, or higher or lower then the electromotive forces in the branches C, D, or between the points X and Y of the circuit B, B. If equal, it is evident that current waves of one sign will be opposed in one branch and assisted in the other to such an extent that all of the waves of one sign will pass over one branch and those of opposite sign over the other. If, on the other hand, the electromotive force of the sources E, F, be lower then that between X and Y, the currents in both branches will be alternating, but the waves of one sign will preponderate.

One of the generators or sources of current E, or F, may be dispensed with, but it is preferable to employ both, if they offer an appreciable resistance, as the two branches will be thereby better balanced. The translating or other devices to be acted upon by the current are designated by the letters G, and they are inserted in the branches C, D, in any desired manner, but in order to better preserve an even balance between the branches due regard should be had to the number and character of the devices as will be well understood.

Figures 2, 3, 4, and 5, illustrate what may be termed electro-magnetic devices for accomplishing a similar result. That is to say, instead of producing directly by a generator an electro-motive force in each branch of the circuit, a field or fields of force is established, and the branches led through the same in such manner that an active opposition of opposite effect or direction will be developed therein by the passage or tendency to pass off the alternations of current.

In figure 2, for example, A is the generator of alternating currents, B, B, the line circuit, and C D the branches over which the alternating currents are directed. In each branch is included the secondary of a transformer or induction coil, which, since they correspond in their functions to the batteries of the previous figure, are designated by the letters E, F.

The primaries H, H' of the induction coils or transformers are connected either in parallel or series with a source of direct or continuous current I, and the number of convolutions is so calculated for the strength of the current from I, that the coils J, J' will be saturated.

The connections are such that the conditions in the two transformers are of opposite character, that is to say, the arrangement is such that a current wave or impulse corresponding in direction with that of the direct current in one primary as H, is of opposite direction to that in the other primary, H', hence it results that while one secondary offers a resistance or opposition to the passage through it of a wave of one sign, the other secondary similarly opposes a wave of opposite sign. In consequence, the waves of one sign will, to a greater or less extent, pass by the way of one branch, while those of opposite sign in like manner pass over the other branch.

In lieu of saturating the primaries by a source of continuous current, they may be included in the branches C, D, respectively, and their secondaries periodically short-circuited by any suitable mechanical devices, such as an ordinary revolving commutator.

It will be understood of course, that the rotation and action of the commutator must be in synchronism or in proper accord with the periods of the alternation in order to secure the desired results.

Such a disposition is represented digrammatically in Figure 3. Corresponding to the previous figures, A is the generator of alternating currents, B, B, the line and C, D, the two branches for the direct currents. In branch C are included two primary coils E, E', and in branch D are two similar primaries F, F'. The corresponding secondaries for these coils and which are on the same subdivided cores J and J', are in circuits, the terminals of which connect to opposite segments K, K' and L, L', respectively of a commutator. Brushes b b bear upon the commutator and alternately short-circuit the plates K and K' and L and L' through a connection c. It is obvious that either the magnets and the commutator or the brushes may revolve.

The operation will be understood from a consideration of the effects of closing or short-circuiting the secondaries. For example, if at the instant when a given wave of current passes, one set of secondaries be short-circuited nearly all the current flows through the corresponding primaries, but the secondaries of the other branch being open circuited, the self-induction in the primaries is highest and hence little or no current will pass through that branch.

If as the current alternates, the secondaries of the two branches are alternately short-circuited, the result will be that the currents of one sign pass over one branch and those of the opposite sign over the other.

The disadvantages of this arrangement which would seem to result from the employment of sliding contacts, is in reality very slight, inasmuch as the electromotive force of the secondaries may be made exceedingly low so that sparking at the brushes is avoided.

Figure 4 is a diagram partly in section of another plan of carrying out the invention.

The circuit B in this case is divided as before and each branch includes the coils of both the field and revolving armatures of two induction devices. The armatures O, P, are preferably mounted on the same shaft, and are adjusted relatively to one another in such manner that when the self-induction in one branch as C is maximum, in the other branch D it is minimum.

The armatures are rotated in synchronism with the alternations from the source A. The winding or position of the armature coils is such that a current in a given direction passed through both armatures would establish in one, poles similar to those in the adjacent poles of the field, and in the other, poles unlike the adjacent field poles, as indicated by n, n, s, s, in the drawing.

If the like poles are presented as shown in circuit D, the condition is that of a closed secondary upon a primary, or in the position of least inductive resistance, hence a given alternation of current will pass mainly through D, A half revolution of the armatures produces an opposite effect and the succeeding current impulse passes through C.

Using this figure as an illustration it is evident that the fields N, M, may be permanent magnets or independently excited and the armatures O,P, driven as in the present case so as to produce alternate currents which will set up alternately, impulses of opposite direction in the two branches D, C, which in such case would include the armature circuits and translating devices only.

In Figure 5 a plan alternative with that shown in Figure 3 is illustrated. In the previous case illustrated, each branch C and D contained one or more primary coils, the secondaries of which were periodically short-circuited, in synchronism with the alternations of current from the main source A, and for this purpose a commutator was employed. The matter may, however, be dispensed with, and an armature with a closed coil substituted.

Referring to Figure 5, in one of the branches, as C, are two coils M' wound on laminated cores and in the other branches D are similar coils N'. A subdivided or laminated armature O' carrying a closed coil R' is rotably supported between the coils M' N' as shown.

In the position shown, that is with the coil R' parallel with the convolutions of the primaries N' M', practically the whole current will pass through branch D, because the self-induction in coils M' M' is maximum. If, therefore, the armature and coil be rotated in synchronism with the alternations of the source A, the same results are obtained as in the case of Figure 3.

Figure 6 is an instance of what may be called in distinction to the others, a magnetic means of securing the results arrived at in this invention. V and W are two strong permanent magnets, provided with armatures V' W' respectviely. The armatures are made of thin laminae of soft iron or steel, and the amount of magnetic metal which they contain is so calculated that they will be fully or nearly saturated by the magnets. Around the armatures are coils E F, contained respectively in the circuits C and D.

The connections and electrical conditions in this case are similar to those in Figure 2, except that the current source I of Figure 2 is dispensed with and the saturation of the core of coils E F obtained from the permanent magnets.

In the illustrations heretofore given, the two branches or paths containing the translating or induction devices and in each instance shown as in derivation one to the other, but this is not always necessary.

For example, in Figure 7, is an alternating current generator, B, B, the line wires or circuit. At any given point in the circuit two paths as D D', are formed, and at another point two paths as C C'. Either pair of group of paths is similar to the previous dispositions with the electrical source or induction device in one branch only, while the two groups taken together form the obvious equivalent of the cases in which an induction device or generator is included in both branches.

In one of the paths as D are included the devices to be operated by the current. In the other branch as D' is an induction device that opposes the current impulses of one direction and directs them through the branch D. So also in branch C are translating devices G and in the branch C' an induction device or its equivalent that diverts through C, impulses of opposite direction to those diverted by the device in branch D'.

A special form of induction device for this purpose is also shown. J J' are the cores formed with pole pieces upon which are wound the coils M N. Between these pole pieces are mounted at right angles to one another the magnetic armatures O P, preferably mounted on the same shaft and designed to be rotated in synchronism with the alternations of current. When one of the armatures is in line with the poles or in the position occupied by armature P, the magnetic circuit of the induction device is practically closed, hence there will be the greatest opposition to the passage of a current through coils N N. The alternation will therefore pass by way of branch D; at the same time, the magnetic circuit of the other induction device being broken be the position of the armature O, there will be less opposition to the current in coils M which will shunt the current from branch C.

A reversal of the current being attended by a shifting of the armatures the opposite effect is produced.

There are many other modifications of the means or methods of carrying out this invention, but it is not deemed necessary herein to specifically refer to more then those described as they involve the chief modifications of the plan. In all of these it will be observed that there is developed in one or all of the branches of a circuit from a source of alternating currents an active (as distinguished from a dead) resistance, or opposition to the currents of one sign for the purpose of diverting the currents of that sign through the other or another path, but permitting the currents of opposite sign to pass without substantial opposition.

Whether the division of the currents or waves of current of opposite sign be effected with absolute precision or not is immaterial to the invention since it will be sufficient if the waves are only partially diverted or directed, for in such case the preponderating influence in each branch of the circuit of the waves of one sign secures the same practical results in many if not all respects as though the current were direct and continuous.

An alternating and direct current have been combined so that the waves of one direction or sign were partially or wholly overcome by the direct current, but by this plan only one set of alternations are utilized, whereas by this system the entire current is rendered available.

By obvious applications of this discovery, it is possible to produce a self-exciting alternating dynamo, or to operate direct current meters on alternating current circuit, or to run various devices, such as arc lamps, by direct currents in the same circuit with incandescent lamps or other devices run by alternating currents.

CLAIMS.

1. The method herein set forth of obtaining direct from alternating currents, which consists in developing or producing in one branch of a circuit from an alternating current source an active resistance to the current impulses of one direction, whereby the said currents or waves of current will be diverted or directed through another branch.

2. The method of obtaining direct from alterna-

influence in each branch of the circuit of the waves of one sign secures the same practical results in many if not all respects as though the current were direct and continuous.

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CLAIMS.

1. The method herein set forth of obtaining direct from alternating currents, which consists in developing or producing in one branch of a circuit from an alternating current source an active resistance to the current impulses of one direction, whereby the said currents or waves of current will be diverted or directed through another branch.

2. The method of obtaining direct from alterna-

ting currents, which consists in dividing the path of an alternating current into branches and developing in one of said branches, either permanently or periodically, an electrical force or active resistance counter to or opposing the currents or current waves of one sign, and in the other branch a force counter to or opposing the currents or current waves of opposite sign, as set forth.

3. The method of obtaining direct from alternating currents, which consists in dividing the path of the alernating current into branches, establishing fields of force and leading the said branches through said fields of force in substantially the manner set forth, whereby electro-motive forces of opposite direction will be produced therein.

4. The combination with the branches of a divided circuit carrying alternating currents, of devices including in or connected with the said branches and capable of developing or exerting an active opposition or electro-motive force counter to the current waves of one direction or sign, as herein set forth.

New York December 16th
1889.

Nikola Tesla

Signed in the presence of-

Robt F. Gaylord
Parker W. Page

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Fig. 1

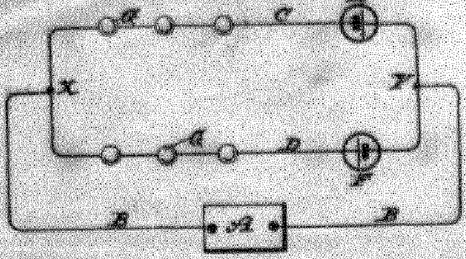


Fig. 2

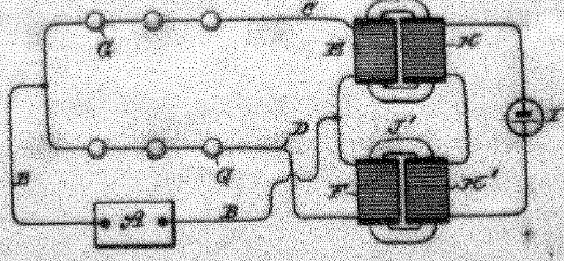


Fig. 3

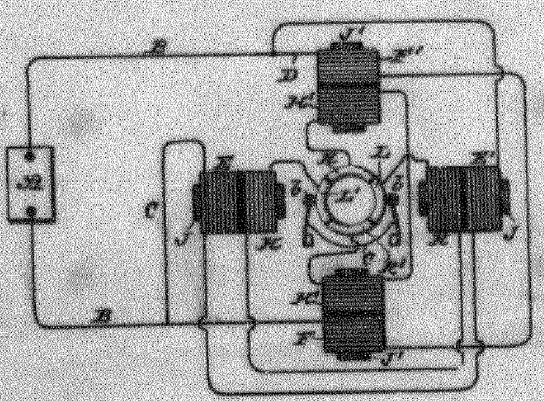


Fig. 4

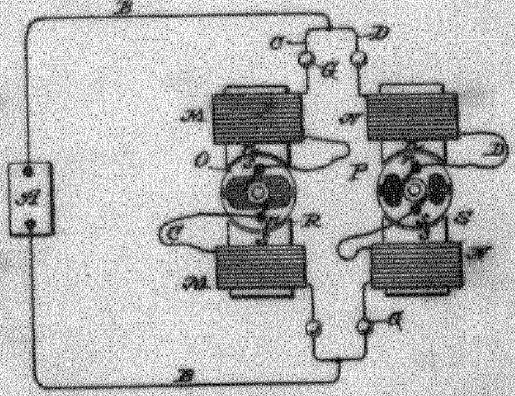


Fig. 5

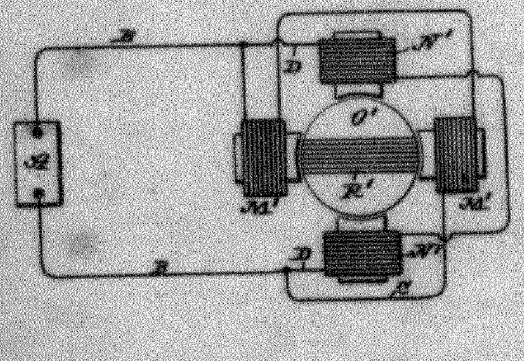


Fig. 6

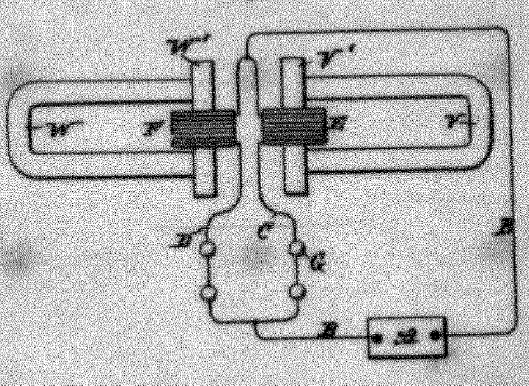
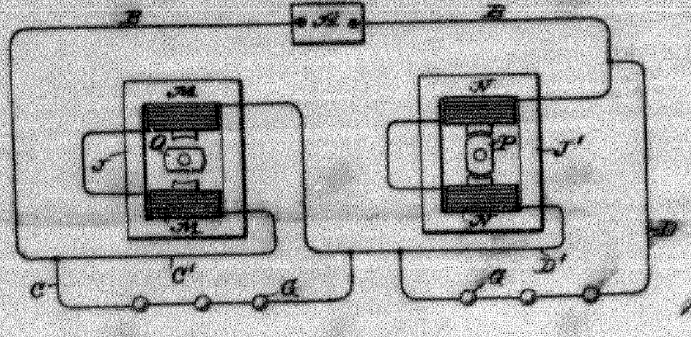


Fig. 7



Nikola Tesla
Inventor

Witnesses:
John Crist
N. S. Stanley

Certified to be the drawings referred to in the specification hereunto annexed.

[illegible] Dec. 10th, 1888

By Henry Crist
Attorneys.

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(30) Priority:			

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(54) **ELECTRICAL ENERGY TRANSMISSION**
(54) **TRANSMISSION D'ENERGIE ELECTRIQUE**

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142352

To all whom it may concern:

Be it known that I, Nikola Tesla, a citizen of the United States, residing in the Borough of Manhattan, in the City, County, and State of New York, have discovered a new and useful Improvement in the Art of Transmitting Electrical Energy Through the Natural Mediums of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is known since a long time that electric currents may be propagated through the earth, and this knowledge has been utilized in many ways in the transmission of signals and the operation of a variety of receiving devices remote from the source of energy, mainly with the object of dispensing with a return conducting-wire. It is also known that electrical disturbances may be transmitted through portions of the earth by grounding only one of the poles of the source, and this fact I have made use of in systems which I have devised for the purpose of transmitting through the natural media intelligible signals or power and which are now familiar; but all experiments and observations heretofore made have tended to confirm the opinion held by the majority of scientific men that the earth, owing to its immense extent, although possessing conducting properties, does not behave in the manner of a conductor of limited dimensions with respect to the disturbances produced, but, on the contrary, much like a vast reservoir or ocean, which, while it may be locally disturbed by a commotion of some kind remains unresponsive and quiescent in a large part or as a whole. Still another fact now of common knowledge is that when electrical waves or oscillations are impressed upon such a conducting-path as a metallic wire reflection takes place under certain conditions from the ends of the wire, and in consequence of the interference of the impressed and reflected oscillations the phenomenon of "stationary waves" with maxima and minima in definite fixed positions is produced. In any case the existence of these waves indicates that some of the outgoing waves have reached the boundaries of the conducting-path and have been reflected from the same. Now I have discovered that notwithstanding its vast dimensions and contrary to all observations heretofore made the terrestrial globe may in a large part or as a whole behave toward disturbances impressed upon it in the same manner as a conductor of limited size, this fact being demonstrated by novel phenomena, which I shall hereinafter describe.

In the course of certain investigations which I carried on for the purpose of studying the effects of lightning discharges upon the electrical condition of the earth I observed that sensitive receiving instruments arranged so as to be capable of responding to electrical disturbances created by the discharges at times failed to respond when they should have done so, and upon inquiring into the causes of this unexpected behavior I discovered it to be due to the character of the electrical waves which were produced in the earth by the lightning discharges and which had nodal regions following at definite distances the shifting source of the disturbances. From data obtained in a large number of observations of the maxima and minima of these waves I found their length to vary approximately from twenty-five to seventy kilometers, and these results and certain theoretical deductions led me to the conclusion that waves of this kind may be propagated in all directions over the globe and that they may be of still more widely differing lengths, the extreme limits beingimposed by the physical dimensions and properties of the earth. Recognizing in the existence of these waves an unmistakable evidence that the disturbances created had been conducted from their origin to the most remote portions of the globe and had been thence reflected, I conceived the idea of producing such waves in the earth by artificial means with the object of utilizing them for many useful purposes for which they are or might be found applicable. This problem was rendered extremely difficult owing to the immense dimensions of the planet, and consequently enormous movement of electricity or rate at which electrical energy had to be delivered in order to approximate, even in a remote degree, movements or rates which are manifestly attained in the displays of electrical forces in nature and which seemed at first unrealizable by any human agencies; but by gradual and continuous improvements of a generator of electrical oscillations, which I have described in my United States patents Nos. 645,576 and 649,621, I finally succeeded in reaching electrical movements or rates of delivery of electrical energy not only approximating, but, as shown in many comparative tests and measurements, actually surpassing those of lightning discharges, and by means of this apparatus I have found it possible to reproduce whenever desired phenomena in the earth the same as or similar to those due to such discharges. With the knowledge of the phenomena discovered by me and the means at command for accomplishing these results I am enabled not only to carry out many operations by the use of known instruments, but also to offer a solution for many important problems involving the operation or control of remote devices which for want of this knowledge and the absence of these means have heretofore been entirely impossible. For example, by the use of such a generator of stationary waves and receiving

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apparatus properly placed and adjusted in any other locality, however remote, it is practicable to transmit intelligible signals or to control or actuate at will any one or all of such apparatus for many other important and valuable purposes, as for indicating wherever desired the correct time of an observatory or for ascertaining the relative position of a body or distance of the same with reference to a given point or for determining the course of a moving object, such as a vessel at sea, the distance traversed by the same or its speed, or for producing many other useful effects at a distance dependent on the intensity, wave length, direction or velocity of movement, or other feature or p=roperty of disturbances of this character.

I shall typically illustrate the manner of applying my discovery by describing one of the specific uses of the same - namely, the transmission of intelligible signals or messages between distant points - and with this object reference is now made to the accompanying drawings, in which -

Figure 1 represents diagrammatically the generator which produces stationary waves in the earth, and Fig. 2 an apparatus situated in a remote locality for recording the effects of these waves.

In Fig. 1, A designates a primary coil forming part of a transformer and consisting generally of a few turns of a stout cable of inappreciable resistance, the ends of which are connected to the terminals of a source of powerful electrical oscillations, diagrammatically represented by G. This source is usually a condenser charged to a high potential and discharged in rapid succession through the primary, as in a type of transformer invented by me and now well known; but when it is desired to produce stationary waves of great lengths an alternating dynamo of suitable construction may be used to energize the primary A. C is a spirally-wound secondary coil within the primary having the end nearer to the latter connected to the ground E and the other end to an elevated terminal D. The physical constants of coil C, determining its period of vibration, are so chosen and adjusted that the secondary system E C D is in the closest possible resonance with the oscillations impressed upon it by the primary A. It is, moreover, of the greatest importance in order to still further enhance the rise of pressure and to increase the electrical movement in the secondary system that its resistance be as small as practicable and its self-induction as large as possible under the conditions imposed. The ground should be made with great care, with the object of reducing its resistance. Instead of being directly grounded, as indicated, the coil C may be joined in series or otherwise to the primary A, in which case the latter will be connected to the plate E; but be it that none or a part or all of the primary or exciting turns are included in the coil C the total length of the conductor from the ground-plate E to the elevated terminal D should be equal to one-quarter of the wave length of the electrical disturbance in the system E C D or else equal to that length multiplied by an odd number. This relation being observed, the terminal D will be made to coincide with the points of maximum pressure in the secondary or excited circuit, and the greatest flow of electricity will take place in the same. In order to magnify the electrical movement in the secondary as much as possible, it is essential that its inductive connection with the primary A should not be very intimate, as in ordinary transformers, but loose, so as to permit free oscillation - that is to say, their mutual induction should be small. The spiral form of coil C secures this advantage, while the turns neat the primary A are subjected to a strong inductive action and develop a high initial electromotive force. These adjustments and relations being carefully completed and other constructive features indicated rigorously observed, the electrical movement produced in the secondary system by the inductive action of the primary A will be enormously magnified, the increase being directly proportionate to the inductance and frequency and inversely to the resistance of the secondary system. I have found it practicable to produce in this manner an electrical movement thousands of times greater than the initial - that is, the one impressed upon the secondary by the primary A - and I have thus readhed activities or rates of flow of electrical energy in the system E C D measured by many tens of thousands of horsepower. Such immense movements of electricity give rise to a variety of novel and striking phenomena, among which are those already described. The powerful electrical oscillations in the system E C D being communicated to the ground cause corresponding vibrations to be propagated to distant parts of the globe, whence they are reflected and by interference with the outgoing vibrations produce stationary waves the crests and hollows of which lie in parallel circles relatively to which the ground-plate E may be considered to be the pole. Stated otherwise, the terrestrial conductor is thrown into resonace with the oscillations impressed upon it just like a wire. More than this, a number of facts ascertained by me clearly show that the movement of electricity through it follows certain laws with nearly mathematical rigor. For the present it will be sufficient to state that the planet behaves like a perfectly smooth or polished conductor of inappreciable resistance with capacity and self induction uniformly distributed along the axis of symmetry of wave propagation and transmitting slow electrical oscillations without sensible distortion and attenuation.

Besides the above three requirements seem to be essential to the establishment of the resonating condition.

First. The earth's diameter passing through the pole should be an odd multiple of the quarter wave length - that is, of the ratio between the velocity of light - and four times the frequency of the currents.

Second. It is necessary to employ oscillations in which the rate of radiation of energy into space in the form of hertzian or electromagnetic waves is very small. To give an idea, I would say that the frequency should be smaller than twenty thousand per second, though shorter waves might be practicable. The lowest frequency would appear to be six per second, in which case there will be but one node, at or near the ground-plate, and, paradoxical as it may seem, the effect will increase with the distance and will be greatest in a region diametrically opposite the transmitter. With oscillations still slower the earth, strictly speaking, will not resonate, but simply act as a capacity, and the variation of potential will be more or less uniform over its entire surface.

Third. The most essential requirement is, however, that irrespective of frequency the wave or wave-train should continue for a certain interval of time, which I have estimated to be not less than one-twelfth or probably 0.08484 of a second and which is taken in passing to and returning from the region diametrically opposite the pole over the earth's surface with a mean velocity of about four hundred and seventy-one thousand two hundred and forty kilometers per second.

The presence of the stationary waves may be detected in many ways. For instance, a circuit may be connected directly or inductively to the ground and to an elevated terminal and tuned to respond more effectively to the oscillations. Another way is to connect a tuned circuit to the ground at two points lying more or less in a meridian passing through the pole E or, generally stated, to any two points of a different potential.

In Fig. 2 I have shown a device for detecting the presence of the waves such as I have used in a novel method of magnifying feeble effects which I have described in my United States patents Nos. 685,953 and 685,955. It consists of a cylinder of insulating material, which is moved at a uniform rate of speed by clockwork or other suitable motive power and is provided with two metal rings B B, upon which bear brushes a and a', connected, respectively, to the terminal plates P and P'. From the rings B B extend narrow metallic segments s and s', which by the rotation of the cylinder are brought alternately into contact with double brushes b and b', carried by and in contact with conducting-holders h and h', supported in metallic bearings D' D', as shown. The latter are connected to the terminals T and T' of a condenser C', and it should be understood that they are capable of angular displacement as ordinary brush-supports. The object of using two brushes, as b and b', in each of the holders h and h' is to vary at will the duration of the electric contact of the plates P and P' with the terminals T and T', to which is connected a receiving-circuit including a receiver R and a device d, performing the duty of closing the receiving-circuit at predetermined intervals of time and discharging the stored energy through the receiver. In the present case this device consists of a cylinder made partly of conducting and partly of insulating material e and e', respectively, which is rotated at the desired rate of speed by any suitable means. The conducting part e is in good electrical connection with the shaft S and is provided with tapering segments f f, upon which slides a brush k, supported on a conducting-rod l, capable of longitudinal adjustment in a metallic support m. Another brush, n, is arranged to bear upon the shaft S, and it will be seen that whenever one of the segments f comes in contact with the brush k the circuit including the receiver R is completed and the condenser discharged through the same. By an adjustment of the speed or rotation of the cylinder d and a displacement of the brush k along the cylinder the circuit may be made to open and close in as rapid succession and remain open or closed during such intervals of time as may be desired. The plates P and P', through which the electrical energy is conveyed to the brushes a and a', may be at a considerable distance from each other in the ground or one in the ground and the other in the air, preferably at some height. If but one plate is connected to earth and the other maintained at an elevation, the location of the apparatus must be determined with reference to the position of the stationary waves established by the generator, the effect evidently being greatest in a maximum and zero in a nodal region. On the other hand, if both plates be connected to earth the points of connection must be selected with reference to the difference of potential which it is desired to secure, the strongest effect being of course obtained when the plates are at a distance equal to half the wave length.

In illustration of the operation of the system let it be assumed that alternating electrical impulses from the generator are caused to produce stationary waves in the earth, as above described, and that the receiving apparatus is properly located with reference to the position of the nodal and ventral regions of the waves. The speed of rotation of the cylinder first described is varied until it is made to turn in synchronism with the alternate impulses of the generator, and the position of the brushes b and b' is adjusted by angular displacement or otherwise, so that they are in contact with the segments s and s' during the periods when the impulses are at or near the maximum of their intensity. These requirements being fulfilled, electrical charges of the same sign will be conveyed to each of the terminals of the condenser, and with each fresh impulse it will be charged to a higher potential. The speed of rotation of the cylinder d being adjustable at will, the energy of any number of separate impulses may thus be accumulated in potential form and discharged through the receiver R upon the brush k coming in contact with one of the segments f. It will be understood that the capacity of the condenser should be such as to allow the storing of a much greater amount of energy than is required for the ordinary operation of the receiver. Since by this method a relatively great amount of energy and in a suitable form may be made available for the operation of a receiver, the latter need not be very sensitive; but when the impulses are very weak or when it is desired to operate a receiver very rapidly any of the well-known sensitive devices capable of responding to very feeble influences may be used in the manner indicated or in other ways. Under the conditions described it is evident that during the continuance of the stationary waves the receiver will be acted upon by current impulses more or less intense, according to its location with reference to the maxima and minima of said waves; but upon interrupting or reducing the flow of the current the stationary waves will disappear or diminish in intensity. Hence a great variety of effects may be produced in a receiver, according to the mode in which the waves are controlled. It is practicable, however, to shift the nodal and ventral regions of the waves at will from the sending-station, as by varying the length of the waves under observance of the above requirements. In this manner the regions of maximum and minimum effect may be made to coincide with any receiving station or stations. By impressing upon the earth two or more oscillations of different wave length a resultant stationary wave may be made to travel slowly over the globe, and thus a great variety of useful effects may be produced. Evidently the course of a vessel may be easily determined without the use of a compass, as by a circuit connected to the earth at two points, for the effect exerted upon the circuit will be greatest when the plates P P' are lying on a meridian passing through ground-plate E and will be nil when the plates are located at a parallel circle. If the modal and ventral regions are maintained in fixed positions, the speed of a vessel carrying a receiving apparatus may be exactly computed from observations of the maxima and minima regions successively traversed. This will be understood when it is stated that the projections of all the nodes and loops on the earth's diameter passing through the pole or axis of symmetry of the wave-movement, are all equal. Hence in any region at the surface the wave length can be ascertained from simple rules of geometry. Conversely, knowing the wave-length, the distance from the source can be readily calculated. In like ways the distance of one point from another, the latitude and longitude, the hour, etc., may be determined from the observation of such stationary waves. If several such generators of stationary waves - preferably of different lengths - were installed in judiciously selected localities, the entire globe could be sub-divided in definite zones of electric activity and such and other important data could be at once obtained by simple calculation or readings from suitably graduated instruments.

The specific plan of producing the stationary waves, herein described, might be departed from. For example, the circuit which impresses the powerful oscillations upon the earth might be connected to the latter at two points.

In collecting the energy of these disturbances in any terrestrial region at a distance from their source, for any purpose and, more especially, in appreciable amounts, the most economical results will be generally secured by the employment of my synchronized receiving transformer. This invention, forming part of my system of transmission of energy through the natural media, has been fully explained in the patents first cited here, but for the better understanding of the present description it is diagrammatically illustrated in Fig. 3. Its most essential part is a circuit E_1 C_1 D_1 which is connected, arranged and adjusted similarly to the transmitting circuit E C D and which is inductively linked with a secondary circuit A_1. The latter, it scarcely need be stated, may be wound with any desired number of turns, such as will be best suited for the operation of the device designated by M. The receiving transformer is closely attuned to the oscillations of the transmitting circuit so that, irrespective of the length of the conductor E_1 C_1 D_1 the points of maximum potential coincide with the elevated terminal D_1 under which conditions the greatest amount of wave energy may be collected and rendered available in the secondary circuit A_1

for useful purposes.

To complete this description, it may be stated that when it is desired to operate, independently, a great many receiving devices, by such stationary waves of different lengths, the principles which I have set forth in my British patent 14,579 (1901) and in my United States patents Nos. 723,188 and 725,605 (1903) may be resorted to for rendering the signals or quantities of energy intended for any ~~particulat~~ particular receiver or receivers non-interfering and non-interferable.

In the above I have briefly outlined my discovery and indicated only a few uses of the same, but it will be readily seem, that it is of transcending importance for the advancement of many arts and industries, new and old, and capable of innumerable valuable applications.

142352

What I claim as my invention is:

1. The art herein described for transmitting electrical energy to a distance consisting in establishing stationary electrical waves in the earth by impressing thereon electrical oscillations of definite frequency.

2. The art herein described for transmitting electrical energy to a distance consisting in establishing electrical oscillations and impressing said oscillations upon the earth and producing therein stationary electric waves.

3. The art herein described for transmitting and utilizing electrical energy consisting in establishing stationary electrical waves in the earth, and operating thereby one or more receiving devices remote from the source of energy.

4. The art herein described for transmitting and utilizing electrical energy consisting in establishing stationary electrical waves in the earth, and operating thereby one or more receiving devices remote from the source of energy and properly located with respect to the position of said waves.

5. The art herein described for transmitting and utilizing electrical energy consisting in establishing stationary electrical waves in the earth, and varying the length of such waves.

6. The art herein described for transmitting and utilizing electrical energy consisting in establishing stationary electrical waves in the earth, and shifting the nodal and ventral regions of said waves.

7. The art herein described for transmitting electrical energy consisting in producing stationary electrical oscillations of definite lengths, impressing said oscillations upon the natural conducting medium and causing thereby a resultant wave or affect to travel slowly over said medium.

8. The art herein described for transmitting electrical energy which consists in establishing stationary electrical waves of different lengths varying the lengths of said waves and causing thereby a resultant wave or affect to travel with the desired velocity throughout the natural medium.

9. The art herein described for transmitting and utilizing electrical energy consisting in establishing stationary electrical waves, impressing said waves upon the natural conducting medium, varying the intensity of said waves and producing thereby perceptible affects in distant receivers.

10. The art of producing affects at a distance consisting in establishing stationary electrical waves, impressing said waves upon the terrestrial globe, varying the characteristics and relations of said waves and causing thereby affects in distant receivers.

11. The art herein described for transmitting and utilizing electrical energy consisting in establishing stationary electrical waves, impressing the affect of said waves upon the natural medium, positioning receiving apparatus at different places through said medium and determining from the affects or indications of said receiving apparatus the condition of said medium.

12. The art herein described for transmitting electrical energy consisting in establishing electrical waves of definite length and duration and impressing said waves upon the natural medium and thereby throwing said natural medium into resonance.

13. The art herein described for creating great electrical movements in the natural medium, which consists in establishing electrical waves of definite length and duration and impressing said waves upon said natural medium until the same becomes resonant.

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14. In a system for the transmission of electrical energy, transmitting apparatus comprising a primary exciting circuit energized by a generator of alternating currents and a resonant secondary circuit of high self-induction and small resistance loosely linked with the primary and adapted for throwing the terrestrial globe into resonance, as set forth.

15. In the system for the transmission of electrical energy, a source of primary electrical oscillations such as a condenser circuit and a secondary circuit inductively linked with the same and adapted for throwing the terrestrial globe into resonance, as specified.

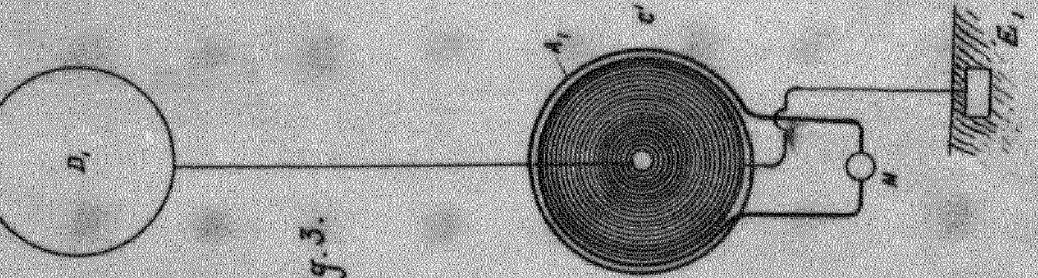


Fig. 3.

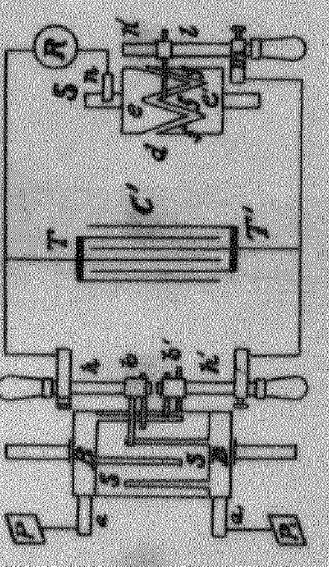


Fig. 2.

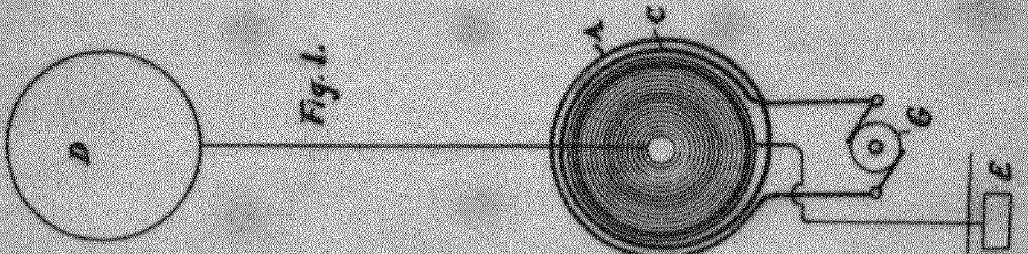


Fig. 1.

Witnesses
Thomas A. Balmer
Harry L. Stanley

Certified to be the drawings referred to
in the Specification hereunto annexed.
Ottawa, Feb 12 1909

Inventor.
N. Tesla
by [illegible]
Atty.

CONFÉDÉRATION SUISSE

BUREAU FÉDÉRAL DE LA PROPRIÉTÉ INTELLECTUELLE

EXPOSÉ D'INVENTION

Brevet N° 15542 26 octobre 1897, 6½ h., p. **Classe 98**

Nikola TESLA, à NEW-YORK (États-Unis, A. du N.).

Installation pour la transmission d'énergie électrique.

Il est reconnu que si l'air renfermé dans un vase est raréfié, ses propriétés isolatrices sont diminuées à tel point qu'il devient un conducteur d'électricité, mais un conducteur à haute résistance.

On sait également surtout depuis les recherches de Heinrich Herz, que certaines ondes électriques peuvent être transmises dans l'atmosphère et l'on a trouvé que ces ondes peuvent influencer certains appareils récepteurs délicats à une distance déterminée de la source de perturbation électrique.

L'invention qui fait l'objet de la présente demande de brevet consiste en une nouvelle installation pour la transmission de l'énergie électrique sans emploi de lignes conductrices métalliques, et elle est principalement destinée à être employée dans les cas où de grandes quantités d'énergie électrique doivent être transmises à de grandes distances.

L'installation pour la transmission d'énergie électrique, qui fait l'objet de mon invention, nécessite pour obtenir des résultats pratiques un appareil pour la production et la conversion de pressions électriques excessivement hautes. Jusqu'ici l'on ne pouvait produire, au moyen des appareils dont on disposait, que des pressions électriques modérées, et cela non sans dangers et difficultés; cet appareil qui fait partie de l'objet de l'invention permet de produire facilement et sans danger des pressions électriques de centaines de mille et même de millions de Volts.

J'ai découvert certains faits très importants et utiles qui rendent pratiquable l'installation de transmission d'énergie électrique décrit ci-après à titre d'exemple.

Ces faits qui ont un rapport direct avec l'invention, sont, entre autres, les suivants: Premièrement: que, avec des pressions électriques telles qu'il est possible d'en produire avec ledit appareil, l'atmosphère devient, dans une certaine mesure, capable de servir de conducteur pour la transmission du courant; Secondement: que la conductibilité de l'air augmente si essentiellement avec l'augmentation de la pression électrique et du degré de raréfaction, qu'il est possible de transmettre à travers une couche même modérément raréfiée de l'atmosphére, de l'énergie électrique en n'importe quelle quantité et à n'importe quelle distance.

L'installation qui fait l'objet de mon invention a pour but de produire en un point déterminé une pression électrique très-haute, de conduire le courant qui en résulte à la terre et à un conducteur terminal à une hauteur à laquelle l'atmosphère sert de conducteur pour ledit courant, et de recevoir le courant dans un second conducteur terminal élevé à une certaine distance du premier, les ondes électriques émises par le premier de ces conducteurs étant reçues par le second.

Pour obtenir ce résultat, il est nécessaire d'employer un appareil capable de produire des pressions électriques considérablement plus hautes que celles produites jusqu'ici, et de conduire le courant à la terre et à un conducteur terminal maintenu à une hauteur où l'atmosphère raréfiée soit capable de conduire librement le courant spécial produit; puis de maintenir en un point éloigné où l'énergie doit être utilisée, un conducteur terminal à la même hauteur, ou à peu près, pour recevoir le courant et le conduire à la terre par un dispositif convenable pour le transformer et l'utiliser.

L'installation et représenté, à titre d'exemple dans le dessin ci-joint qui en est un diagramme.

A est un enroulement, généralement de plusieurs tours et de très grand diamètre, enroulé en spirale autour d'un noyau magnétique ou de fer doux. *C* est un second enroulement formé par un conducteur beaucoup plus gros et plus court, enroulé à proximité de l'enroulement *A*.

Dans l'installation de transmission la bobine *A* constitue l'enroulement secondaire à haute tension, et la bobine *C* l'enroulement primaire à tension beaucoup plus faible d'un transformateur. Une source convenable de courant *G* est comprise dans le circuit de l'enroulement primaire *C*.

Une borne de l'enroulement secondaire *A* se trouve au centre de la bobine spirale, et de cette borne le courant est amené par un conducteur *B* à un conducteur terminal *D*. Chaque conducteur terminal peut être formé, p. ex. d'un ballon ou cerf-volant recouvert de staniol ou d'une plaque ou boule métallique suspendue à un ballon ou cerf-volant.

L'autre borne de l'enroulement secondaire *A* est reliée à la terre et en outre au primaire afin que ce dernier ait approximativement le même potentiel que les parties adjacentes du secondaire, ce qui donne de la sécurité.

Un transformateur de construction semblable est employé à la station réceptrice, mais ici le long enroulement A^1 constitue le primaire, et l'enroulement court C^1, le secondaire du transformateur. Des lampes *L*, moteurs *M*, ou autres dispositifs pour l'utilisation du courant, sont disposés dans le circuit de l'enroulement secondaire. Le conducteur terminal élevé D^1 est relié avec le centre de la bobine A^1, et l'autre borne de ladite bobine est reliée à la terre et de préférence également à la bobine C^1, pour les raisons indiquées ci-dessus.

Dans des bobines du genre décrit, le potentiel augmente graduellement avec le nombre de tours, la différence de potentiel entre deux tours adjacents étant relativement petite, et l'on obtient un très-haut potentiel ce qui est impraticable avec les bobines ordinaires.

L'élévation des conducteurs terminaux *D* D^1 devra être déterminée non seulement par la condition de l'atmosphère, mais encore par la nature de la contrée environnante.

Ainsi, s'il y a des montagnes dans le voisinage, les conducteurs terminaux devront être à une plus grande hauteur, et en général ils devront toujours se trouver à une hauteur beaucoup plus grande que la hauteur des plus hauts objets qui les entourent, afin de diminuer la perte. Etant donné que, au moyen du dispositif décrit, on peut produire n'importe quel potentiel; les courants à travers la couche d'air pourront être très petits, ce qui diminue la perte dans l'air.

EN RÉSUMÉ,

Je revendique comme mon invention:

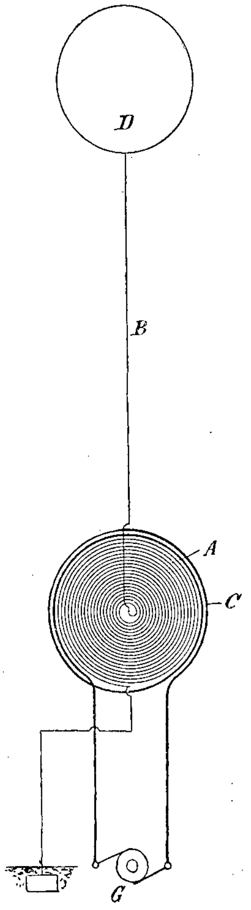
Une installation pour la transmission d'énergie électrique, caractérisée par une source quelconque de courant électrique *G*, intercalée dans un enroulement primaire *C*, un enroulement secondaire *A*, plus long que *C* disposé en spirales autour d'un noyau magnétique et entouré par le primaire *C*, l'une des extrémités de l'enroulement *A* étant reliée au primaire *C* et à la terre, l'autre de ses extrémités étant reliée à un conducteur terminal aérien D, en combinaison avec un autre conducteur terminal aérien D^1 relié à l'une des extrémités d'un enroulement A^1 dont l'autre extrémité est reliée à la terre et qui est placé dans un enroulement C^1 plus court que A^1 et relié à un circuit électrique de consommation.

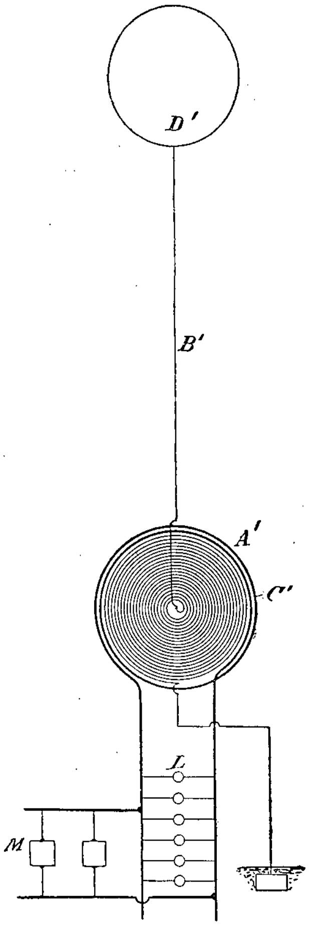
Nikola TESLA.

Mandataire: E. IMER-SCHNEIDER, à GENÈVE.

Nikola Tesla.
26 octobre 1897.

Brevet N° **15542.**
1 feuille.





CONFÉDÉRATION SUISSE

BUREAU FÉDÉRAL DE LA PROPRIÉTÉ INTELLECTUELLE

EXPOSÉ D'INVENTION

Brevet N° 18652 20 janvier 1899, $6^{1}/_{2}$ h. p. **Classe 98**

Nikola TESLA, à New-York (Etats-Unis, A. du N.).

Installation pour commander la marche des machines d'un véhicule automobile d'un point éloigné du véhicule.

Le problème de l'invention est celui de commander à distance d'un véhicule, la marche des machines de propulsion et de toutes sortes portées par ce véhicule quelconque.

En un point quelconque est disposée une source capable d'émettre à volonté des ondes électriques. Ces ondes électriques se transmettent en toutes directions et vont frapper les organes récepteurs disposés à leur intension sur le véhicule en quelque lieu qu'il se trouve (pourvu qu'il soit naturellement encore dans le champ d'action desdites ondes). Les organes récepteurs agissent sur les appareils commandant la marche des différentes machines du véhicule dès qu'ils reçoivent lesdites ondes électriques.

Dans les dessins ci-joints donnés à titre d'exemple, j'ai choisi comme véhicule un bateau flottant dont les appareils permettent de commander à distance les machines destinées à le faire mouvoir, à le diriger et enfin à exercer sur lui une operation mécanique quelconque, p. ex. de lancer une torpille à un moment donné.

La fig. 1 est une vue en plan du bateau et de ses machines;

La fig. 2 est une coupe longitudinale dudit;

La fig. 3 est une vue en plan du bateau. Elle est partiellement schématique en ce qui concerne les appareils et les circuits;

La fig. 4 est une vue en plan à une échelle agrandie de la combinaison du récepteur d'ondes proprement dit ou cohéreur et du mécanisme de commande de la marche des machines;

La fig. 5 est une vue en élévation principale de ladite combinaison;

La fig. 6 montre la même en élévation latérale;

La fig. 7 est une vue latérale d'un détail du mécanisme;

La fig. 8 est une coupe axiale à une échelle agrandie du cohéreur, auquel aboutit le circuit récepteur des ondes électriques;

La fig. 9 est une représentation schématique de l'ensemble de l'installation comprenant le générateur des ondes électriques et le bateau;

La fig. 10 représente le schéma complet de la mise en circuit des appareils du bateau.

Le bateau *A* est pourvu d'un dispositif propulseur convenable comprenant une hélice *C* fixée dans le prolongement de l'arbre d'un moteur électro-magnétique *D* alimenté par des accumulateurs électriques *E*. Il porte aussi un plus petit moteur *F* servant à manœuvrer le gouvernail et dont l'arbre est prolongé au delà de l'un des paliers et porte une vis sans fin qui engrène dans une roue dentée *G*. Cette dernière est fixée sur un canon *b* pivotant librement sur la tige verticale *H* et l'entraîne dans l'une ou l'autre direction suivant la direction de la rotation du moteur *F*.

Le canon *b* porte la roue d'engrenage H' qui engrène avec la roue H'' clavetée sur l'arbre G' du gouvernail F'.

Je décrirai maintenant les mécanismes par lesquels il est possible de mettre en marche ou d'arrêter ces deux moteurs.

Me référant à la fig. 9, *S* désigne une source quelconque d'ondes électriques dont la production a lieu lorsque la manette d'un interrupteur s'arrête sur quatre points $t\ t'\ u\ u'$; donc quand la manette passe rapidement sur lesdits points, les oscillations ne sont produites par la source que pendant un très petit intervalle de temps. Quatre fois les ondes jaillissent à chaque tour entier de la manette. Ces ondes rencontrent le circuit récepteur dont l'ajustement est tel que sa période d'oscillation naturelle soit la même que celle desdites ondes ou en harmonie avec elle.

Ce circuit récepteur montré en schéma dans les fig. 3 et 10, comprend une plaque horizontale E', un conducteur C', aboutissant à un cohéreur A' et enfin un conducteur A'' reliant celui-ci au sol par une connexion convenable à la quille métallique B' du bateau.

La plaque E' présente une large surface conductrice et est supportée aussi haut que possible sur un support D' qui est brisé en fig. 2. Il est très important que le conducteur C' soit bien isolé quelle que soit la manière dont il est supporté. En dérivation sur le cohéreur se trouve un circuit local comprenant une batterie a' et un aimant de relais *a*.

Le cohéreur est représenté dans les vues générales fig. 1 et 2 et en détail dans les fig. 4, 6, 7, 8. Il consiste en un cylindre creux de métal *c*, fig. 8, fermé aux deux bouts par des couvercles en matière isolante c' à travers lesquels passe une tige métallique centrale c''. Une petite quantité de grains fins *d* de matière conductrice tel que un métal oxydé est placé dans le cylindre.

Une bande métallique d', fig. 4, 6 et 10, fixée à une borne isolée d'' à laquelle aboutit le conducteur c' applique contre le côté du cylindre *c*, le connectant ainsi avec le conducteur c'. La tige centrale c'' est fixée dans les becs de la fourche métallique *e*, fig. 6, et c'est ainsi que le cylindre *c* est supporté. Cette fourche *e* pivote librement à l'extrémité de l'arbre *h*, fig. 6. Un ressort spiral *i* relie cependant la fourche *e* à l'arbre *h*. L'arbre *h* est composé de deux cylindres métalliques reliés dans les prolongements de leurs axes au moyen d'un canon isolant. L'extrémité de cet arbre *h* sur laquelle se trouve la fourche *e* pivote dans une plaque métallique isolée de la carcasse de l'appareil. Le conducteur A'' part de cette plaque métallique; autour d'une vis fixée dans celle-ci pivote aussi un levier h'', fig. 4, 5, 6 et 7. Dans une rainure pratiquée à l'extrémité de ce levier h'' pivote l'excentrique h' faisant corps avec l'arbre *h*. Le levier h'' porte en outre les goupilles *i* et i', contre l'une ou l'autre desquelles la goupille *p* de la fourche *e* vient buter suivant que l'excentrique a amené le levier h'' dans l'une ou l'autre de ses positions extrêmes.

Sur l'extrémité de l'arbre *h* opposée à la fourche *l* est fixé un pignon d'engrenage engrenant avec une roue dentée située sur l'arbre g', fig. 6, qui fait partie d'un train d'engrenage mû par un mécanisme d'horlogerie *K*. Le rapport des nombres de dents est de deux pour les roues des arbres g' et *h* en sorte que si g' décrit $^1/_4$ de tour *h* en décrit un demi. La roue d'échappement g'' montée sur le prolongement de l'arbre g' du mécanisme d'horlogerie porte quatre chevilles $b_1''\ b_2''\ b_3''\ b_4''$, fig. 4, 5, 6, dont la trajectoire rencontre celle des becs de l'ancre d'échappement *g*. La fig. 5 représente cette ancre dans la position de repos de l'appareil. On voit que si l'électro-aimant dont l'armature fait corps avec l'ancre agit, le bec supérieur de l'ancre abandonne la cheville en prise b_2'', mais la cheville b_1'' qui précède celle-ci (dans le sens inverse aux aiguilles d'une montre) rencontre le plan incliné du bec inférieur de l'ancre ce qui a pour effet de ramener le bec supérieur dans la trajectoire des chevilles et c'est la suivante b_3'', qui par suite viendra en prise avec ledit bec supérieur. La roue g'' décrit donc un quart de tour chaque fois que l'ancre joue. L'arbre h exécute un demi-tour et arme de ce fait le ressort spiral i. Mais d'autre part l'excentrique h' fait pivoter le levier h'' ce qui a pour effet que la cheville i' qui se trouvait en prise avec la goupille p abandonne celle-ci. Le ressort i qui a été armé d'un demi-tour (et qui a d'ailleurs déjà une tension initiale) agissant d'abord sur la fourche e fait décrire à celle-ci un mouvement violent de rotation, qui s'interrompt brusquement au moment où la goupille p rencontre l'autre cheville i' ; celle-ci, du fait du mouvement imprimé au levier h'' par l'excentrique h' étant venue s'interposer dans la trajectoire de la goupille p.

Si donc, comme c'est le cas, l'axe du cohéreur est vertical celui-ci sera aussi vertical après le renversement ensorte que les grains métalliques se trouveront dans les mêmes conditions dans l'intérieur du cylindre.

Je vais maintenant faire voir comment a lieu la commande de l'électro-aimant f puisque c'est du jeu de celui-ci que dépend le fonctionnement de l'échappement. D'après le schéma fig. 10, lorsque les ondes électriques viennent frapper le cohéreur A', les grains du cohéreur acquièrent la propriété de laisser passer le courant que tend à produire la force électromotrice de la pile a'. Ce courant aimante l'électro-aimant de relais a et l'armature e' de celui-ci étant attirée, ferme le circuit d'une batterie b'. Le courant que produit alors cette batterie sert à exciter l'électro-aimant f qui attire son armature f' ce qui a pour effet de dégager celle des chevilles b'' qui est en prise avec le bec supérieur de l'ancre g comme décrit plus haut. Mais dans ce mouvement de déplacement le bras k' de l'ancre g rencontre la tige k, fig. 5, qui oblige l'armature e' de l'aimant a à s'éloigner rompant ainsi le circuit d'excitation de f. La cheville b'' qui vient s'engager sur le plan incliné du bras inférieur g a donc toute facilité pour ramener ledit bras hors de la trajectoire des chevilles, éloignant ainsi l'armature f'. Quant à l'arbre h il décrit le demi-tour comme indiqué ci-dessus et produit le renversement du cohéreur et par là la décohésion ce qui a pour effet d'interrompre le courant de la pile a'. On voit en résumé que chaque fois que les ondes électriques ont amené le jeu de l'appareil, celui-ci se remet automatiquement grâce à la force du ressort du mécanisme d'horlogerie k dans la position de recevoir de nouvelles ondes et le résultat que produisent les ondes est ainsi de faire tourner l'arbre g' d'un quart de tour.

J'utilise ce mouvement de l'arbre g' pour fermer et ouvrir à volonté le circuit des moteurs D et F. A cet effet sur le prolongement de l'arbre g' qui porte le disque d'échappement g'' (fig. 4 et 6) est disposé un cylindre j de matière isolante ayant un disque conducteur à chaque extrémité. Faisant corps l'un avec l'un de ces disques, l'autre avec l'autre, deux segments j' et j'' sont disposés sur les côtés diamétralement opposés du cylindre. Le segment j'' est en connexion électrique avec le bâti de l'instrument grâce aux pivots de l'arbre g', de l'ancre g, etc., tandis que des bandes isolées ou brosses J J' s'appuient l'une contre le disque libre du cylindre j, l'autre contre le manteau de ce dernier.

Trois départs de circuit sont ainsi fournis, l'un toujours en connexion avec le segment j'', le second avec le disque libre du cylindre j et le troisième disposé pour reposer soit sur les segments j ou j'' soit sur les espaces intermédiaires isolants, suivant la position dans laquelle le cylindre j est amené par le mouvement d'horlogerie et l'échappement à ancre g.

K' K'' (fig. 1, 3 et 10) sont deux aimants de relais placés convenablement à l'arrière de l'engin de propulsion. Chacun de ces aimants se trouve intercalé dans les deux circuits qui aboutissent aux brosses précisées J J' et au bâti. Ces deux circuits ont le conducteur qui va de la brosse J' à la batterie k'' et de là aux deux entrées des électro-aimants K' et K'' en commun. Comme conséquence de cet arrangement les relais K' ou K'' fonctionneront, le premier quand la brosse *J'* appuiera sur le segment *j''*, le second quand ce sera sur *j'* et les deux relais seront inactifs pendant que la brosse *J'* est placée sur un espace isolant entre les segments *j'* et *j''*.

Lorsque le relais *K'* est mis en fonction son armature ferme un circuit par le moteur *F* qui est orienté de manière à diriger le gouvernail p. ex. à bâbord.

Quand le relais *K''* est actif, un autre circuit est fermé par le moteur *F* qui renverse le sens de sa rotation et dirige le gouvernail à tribord. Ces circuits sont cependant utilisés dans d'autres buts et ils passent en partie à travers des appareils dont je vais décrire le fonctionnement.

La tige fixe *H*, fig. 2 et 10, porte un disque isolateur fixe *L* (fig. 2) au côté inférieur duquel sont fixés six balais 1 2 3 4 5 et 6 (fig. 3 et 10). Le manchon *b* entourant la tige est mû par le moteur directeur *F* de la manière indiquée ci-dessus et porte un disque en matière isolante *L'* sur la surface supérieure duquel sont fixées en deux cercles concentriques des touches de contact.

Les balais 1 2 3 et 4 appuient sur les touches du cercle intérieur tandis que les balais 5 et 6 appuient sur les touches extérieures.

Le cercle des touches extérieures comprend deux longues touches 7 et 8 diamétralement opposées et une série de touches courtes 9 10 11 12 13 et 14 en avant et en arrière de 7 et 8. Des conducteurs flexibles *l' l''* connectent les plaques 7 et 8 aux bornes du moteur propulseur *D* et les pôles de la batterie principale *E* sont connectés aux balais 5 et 6 respectivement, de façon que tant que le gouvernail est dans sa position moyenne ou tourné à un certain angle d'un côté ou de l'autre, le courant passe dans le moteur propulseur *D* par les balais 5 et 6 et les touches 7 et 8. Le cercle des touches intérieures en comprend deux, 21 et 23, dont la dernière embrasse un angle de 90° environ. Lorsque le gouvernail est droit, les balais 1 2 3 et 4 reposent seulement sur la touche 21. Le moteur de direction *F* est actionné lui aussi par le courant de la batterie principale *E* de la manière suivante: Un conducteur 15, fig. 10, partant d'un des pôles de la batterie, conduit à l'un des balais du collecteur et de l'autre balai part un conducteur 16, qui traverse en série les aimants et l'induit d'un petit moteur *m* et aboutit en se bifurquant aux contacts que commandent les relais *K'* et *K''*. Quand le relais *K''* p. ex. fonctionne, ce circuit 15-16 se ferme par un câble 19, à travers une bobine ou une rangée de bobines d'aimants du moteur *F*, le balai 1, la touche 21 et le conducteur 22. De la même manière, quand l'autre relais, *K'*, fonctionne, le circuit 15-16 se continue par le câble 18 et une rangée de bobines du moteur *P* renversant l'aimantation des aimants de celui-ci jusqu'au balai 2 et retourne de là par la touche 21 et le conducteur 22 à la batterie.

Tant que le gouvernail n'est pas dévié de plus de 45° p. ex., les deux balais 1 et 2 restent toujours en contact avec la longue touche 21. D'ailleurs, au cas ou cet angle limité du gouvernail est atteint, l'un des balais reste toujours néanmoins en contact avec ladite touche 21. De là résulte qu'on peut toujours forcer le moteur *F* à tourner dans l'une ou l'autre direction, quelle que soit la position du gouvernail si celle-ci ne dépasse pas un certain angle p. ex. 45° à droite et à gauche de sa position moyenne. Cet angle de déviation maximum ne peut être dépassé grâce à la touche isolatrice 23. Car les déplacements du gouvernail au delà de cet angle limité, amènent cette touche sous l'un ou l'autre des balais 1 ou 2 et rompt le circuit du moteur *F*. Toutefois ainsi qu'on le comprendra grâce à la longueur de la touche 21, l'appareil est en position pour ramener le gouvernail dans la direction de sa position moyenne. D'une façon analogue le circuit du moteur *D* sera coupé si les petites touches 9 11 12 et 14 sont isolées et viennent prendre place sous les balais 5 et 6. A l'exception d'une, 10 p. ex., les petites touches peuvent être d'autre part connectées entre elles ou au plus grandes de différentes manières p. ex. par des résistances pour produire certains changements de régime sur le moteur *D*, cela p. ex. à la mise en marche. Mais afin de ne pas compliquer le dessin, ces connexions ne sont pas représentées.

Il est important d'ajouter que sur tous les points de contact où une rupture a lieu, l'on dispose des appareils convenables pour empêcher les étincelles et l'oscillation des décharges électriques dans les circuits, car ces étincelles et ces oscillations pourraient détériorer le cohéreur. C'est surtout cette considération qui rend utiles les deux relais *K'* et *K''*, dont on pourrait se dispenser sans cela. Les courants de tension et d'intensité élevées doivent être placés aussi loin que possible du cohéreur afin de protéger celui-ci contre toute action nuisible de ceux-là.

Un petit moteur série *m* est représenté en fig. 1, 3 et 10, lequel peut remplir plusieurs buts. Ce moteur est connecté en série à l'armature du moteur directeur *F* de façon que, quand l'un ou l'autre des circuits de ce dernier est fermé par les relais *K'* ou *K''*, le moteur *m* est aussi mis en rotation et cela dans tous les cas dans le même sens. L'arbre de ce moteur *m* porte un pignon d'engrenage qui actionne une roue à laquelle est fixé un bras *m''* portant une brosse de contact pouvant se déplacer sur une touche concentrique *n*. Un ressort spiral *m'* dont l'une des extrémités est fixée à l'arbre fixe de la roue et l'autre au bras *m''* est armé par la rotation du bras *m''* et ramène celui-ci contre l'arrêt isolé *P* dès que le courant cesse dans le conducteur 16. Grâce à ce que les circuits du moteur *F* sont fermés généralement pendant un temps très court, le levier *m''* ne se déplacera généralement qu'à une petite distance de l'arrêt *P*. Mais si les circuits du moteur *F* sont successivement fermés et rouverts rapidement, le gouvernail étant ainsi autant sollicité à se déplacer dans un sens que dans l'autre restera en place tandis que le levier *m''* qui obéit au moteur *m* dont les déplacements s'additionnent à chaque fermeture du courant, est déplacé alors d'un angle plus grand et arrive en contact avec une touche *n* et même éventuellement avec une borne *n'* si la manœuvre précitée se répète suffisamment longtemps.

Lorsque le levier *m''* arrive en contact avec la touche *n*, une dérivation du courant de la batterie principale *E* passe soit à travers l'un ou l'autre, soit à travers les deux feux supportés par des appuis *o q*, fig. 10, suivant la position des balais 3 et 4 relativement au segment isolateur 23. Mais comme le disque isolant *L* portant les balais est lié au gouvernail, la position de celui-ci est ainsi indiquée d'une manière générale, en observant les feux. Les deux feux peuvent être colorés et en les faisant luire à son gré l'opérateur peut guider la course du bateau dans la nuit. C'est aussi pour faciliter la direction du bateau que les mâts *r r* sont peints en couleurs vives afin d'être visibles de jour à une grande distance. En ouvrant et en fermant les circuits du moteur *F* un nombre suffisant de fois, le levier *m''* arrive en contact avec la borne *n'*, fermant ainsi un circuit en déviation de la batterie principale *E* par un dispositif *o* et faisant agir celui-ci au moment voulu.

Je résumerai maintenant toutes les opérations qu'il y a lieu de faire pour manœuvrer le bateau :

A l'arrêt le disque *L'* est tourné de manière à ce que le balai 2 repose sur la touche isolée 23 et le balai 6 sur l'une des touches isolées, 10 par ex. Dans ces conditions le gouvernail sera tourné à tribord et le circuit du moteur *D* interrompu entre la touche 8 et le balai 6 et entre la touche 7 et le balai 5. En même temps l'un seulement des circuits du moteur *F* (celui qui est actionné par le relais *K''*) peut être fermé lorsqu'on agit sur les relais *K'* et *K''*, le balai 2 connecté à l'autre circuit étant hors de contact avec la longue touche 21. On peut se rendre compte qu'il y a aussi arrêt du moteur *D* lorsque le gouvernail se trouve dévié dans sa position extrême à bâbord. Pour mettre en marche le bateau et le diriger vers un point donné, il faut amener la manette *T*, fig. 9, momentanément en un point *t* p. ex. de l'interrupteur et aussitôt dépasser ce point. Les ondes électriques émises pendant l'instant du contact passent dans le circuit récepteur sur le bateau, sensibilisent le cohéreur *A'* qui laisse alors passer le courant de la pile *a'* à travers le circuit comprenant ledit cohéreur, le relais *a* et la pile *a'*. Le relais *a'* ferme le circuit d'excitation de l'électro-aimant *f* lequel dégage l'échappement. Ceci fait tourner le cylindre *j* et amène le balai *J'* qui se trouvait p. ex. sur la portion isolante en contact avec *j'* pendant que le cohéreur est agité de la manière décrite et redevient impénétrable au courant. Le contact du balai *J'* avec la touche *j'* ferme l'excitation de *K''* lequel ferme le circuit du moteur *F* circuit qui part de la touche 21 connectée en permanence à un pôle de la batterie principale *E* et s'étend par le balai 1, le champ du moteur *F*, le câble 19, l'armature de relais *K''*, le câble 16, le moteur *m*, les balais et le collecteur du moteur *F* et le câble 15 et se termine à la borne formant l'autre pôle de la batterie *E*. Le moteur *F* est ainsi mis en mesure de dévier le gouvernail vers sa position médiane, mais le mouvement du disque *L'* qui s'en suit amène les touches 8 et 7 sous les balais 5 et 6 respectivement et ferme le circuit du moteur propulseur qui met le bateau en marche.

Le moteur *F* continue à tourner jusqu'à ce que le gouvernail ait été amené au point désirable pour la direction du bateau. Pour l'arrêter dans ce point il suffit d'amener la manette momentanément sur le point *u'*, fig. 9. Ceci produit une nouvelle action du relais *a*, de l'électro *f* et de l'échappement et un intervalle du cylindre *j* est amené sous le balai *J'* et le relais *K''* est mis hors d'action, coupant le circuit du moteur *F*.

Le gouvernail reste ainsi dans la position dans laquelle il a été placé par le moteur *F*. Si on désire maintenant le diriger à tribord, soit dans la direction opposée à celle dans laquelle il était déplacé en premier lieu, la manette *T* est simplement à placer au point suivant *t* pendant un moment. Le cylindre *j* ferme alors le circuit d'excitation du relais *K'* qui à son tour ferme l'autre circuit du moteur *F* dont l'excitation a ainsi lieu en sens inverse ce qui change son sens de rotation.

Le déplacement de la manette *T* sur le point suivant *u* coupe le circuit du relais *K'* et ainsi arrête le moteur *F*. Un nouveau déplacement de la manette sur le point initial *t* dirigera le gouvernail à bâbord et ainsi de suite. On voit d'ailleurs que pour arrêter les deux moteurs, il suffit de laisser tourner le moteur *F* suffisamment longtemps pour que les touches 23 et 10 arrivent sous les balais 1 ou 2 pour la première et 5 ou 6 pour la seconde respectivement. Il est de plus évident qu'un des relais *K'* ou *K''* fonctionnera toujours pour mettre en mouvement le moteur *F*. Si cela n'a pas lieu, grâce à la touche isolante 23 après le passage de la manette *T* sur les deux premiers points *t* et *u* p. ex., ce sera certainement après le passage de ladite manette sur le point *u'*. Pour n'avoir pas de crainte que le phénomène que l'on désire produire au moyen du dispositif *O*, fig. 10, n'arrive intempestivement, il suffit que la plus longue période d'activité dont le moteur *F* ait besoin dans les conditions ordinaires ne permette pas au moteur *m* de mettre le bras *m'* en contact avec la borne *n'*. Un arrêt de courte durée du courant dans le moteur *F* permet d'ailleurs à la force antagoniste du ressort *m'* de ramener le bras à l'arrêt *P*. Pour produire le phénomène en *O* il suffit de tourner la manette *T* avec une certaine rapidité. Des courants momentanés seront dirigés ainsi à travers le moteur *F* dans des directions opposées; ce moteur ne sera donc pas sensiblement dévié en somme, mais comme ces courants ont le même sens dans le moteur *m*, les déviations qu'ils produisent de son armature, s'additionnent jusqu'au moment où le bras *m''* arrive à toucher la borne *n'*.

L'invention décrite sera utile de bien des manières. Des véhicules de n'importe quelle espèces pourront être employés, tels que: bateaux de sauvetage, bateaux de poste ou bateaux pilotes, ou d'autres semblables, ou pour porter des lettres, des paquets, des provisions, des instruments, des objets ou du matériel de n'importe quel genre, pour établir des communications avec des régions inaccessibles et les explorer, pour tuer ou capturer des baleines ou d'autres animaux marins et dans beaucoup d'autres buts scientifiques ou commerciaux. Mais la plus grande valeur de mon invention résultera de son effet sur les armements de guerre, car en raison de son pouvoir de destruction certain et illimité, elle tendra à amener et à maintenir la paix parmi les nations.

REVENDICATIONS:

1° Une installation pour commander la marche des machines d'un véhicule automobile d'un point éloigné du véhicule, caractérisée par un appareil capable de produire des ondes électriques destinées à être communiquées au véhicule à travers l'espace et par un appareil récepteur situé sur ledit véhicule et disposé pour effectuer la commande de l'engin propulseur, de l'engin de direction et d'autres mécanismes placés sur ledit véhicule;

2° Dans une installation telle que revendiquée sous chiffre 1, un cohéreur disposé de façon à ce que la décohésion s'opère par le renversement du cohéreur;

3° Dans une installation telle que spécifiée sous chiffre 1, un cohéreur disposé de façon à ce que la décohésion s'opère par la rotation du cohéreur sur un mobile d'un mécanisme d'horlogerie dont l'échappement est actionné par un électro-aimant mis en action lui-même par le courant de passage du cohéreur.

Nikola TESLA.

Mandataire: E. IMER-SCHNEIDER, à Genève.

Nikola Tesla.
20 janvier 1899.

Brevet N° 18652.
2 feuilles No. 1.

Fig. 1

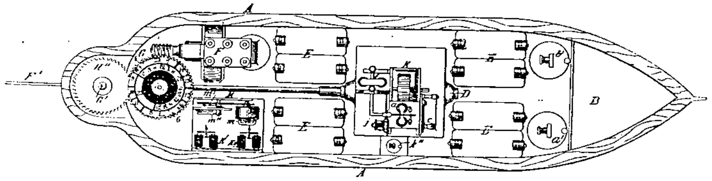


Fig. 5

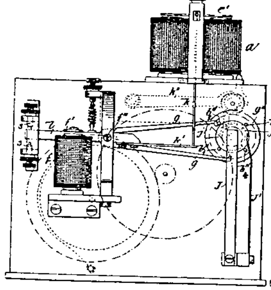


Fig. 6

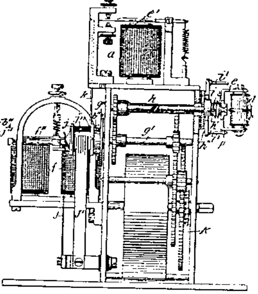


Fig. 2

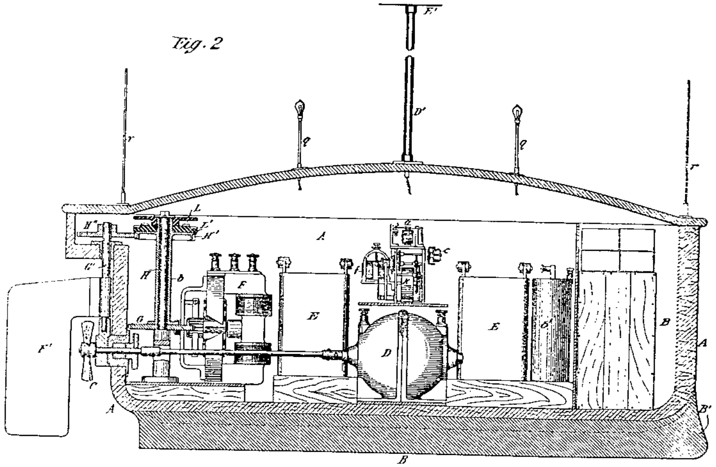


Fig. 4

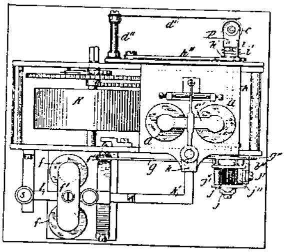


Fig. 8

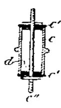
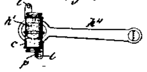


Fig. 7



Nikola Tesla.
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Fig. 1

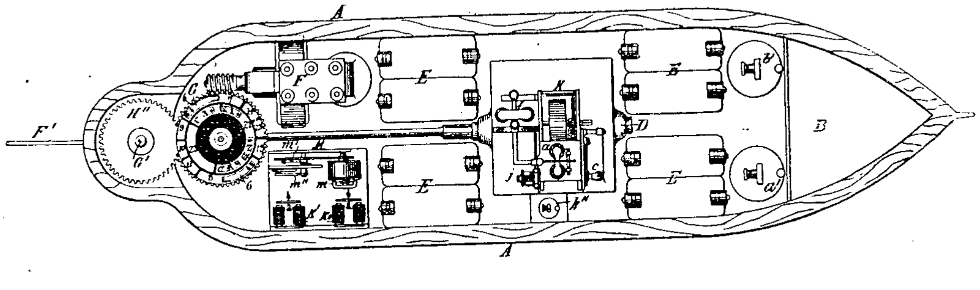
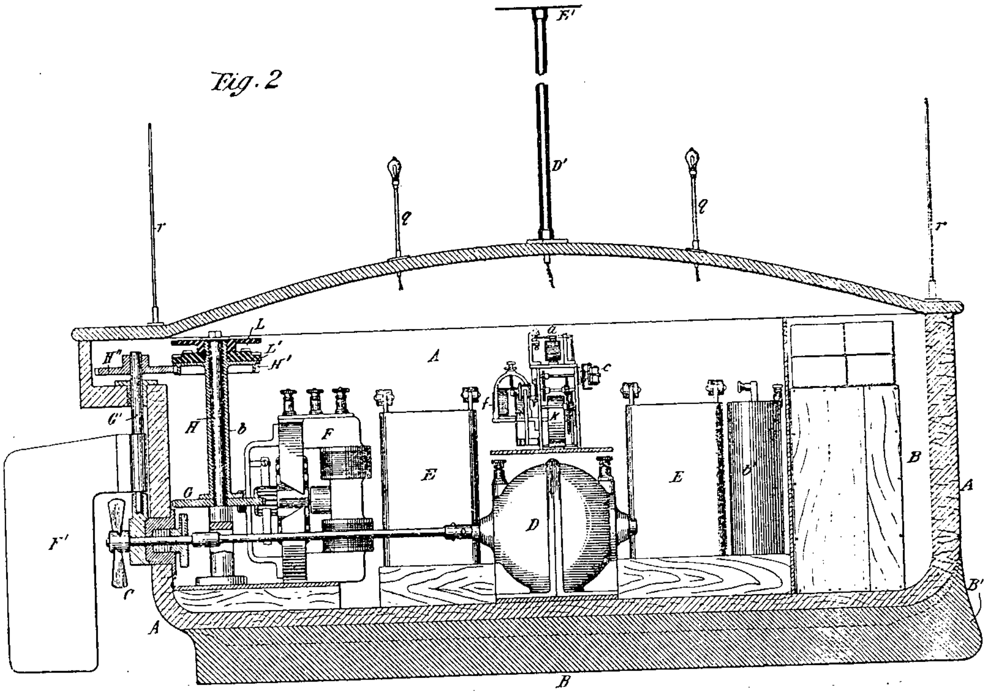


Fig. 2



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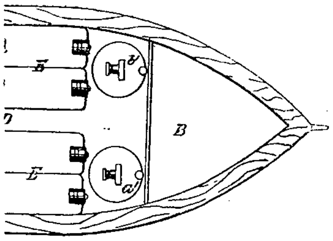


Fig. 5

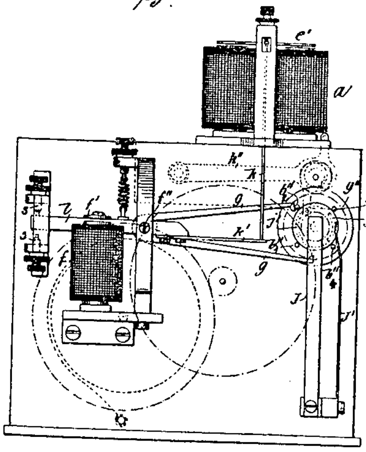


Fig. 6

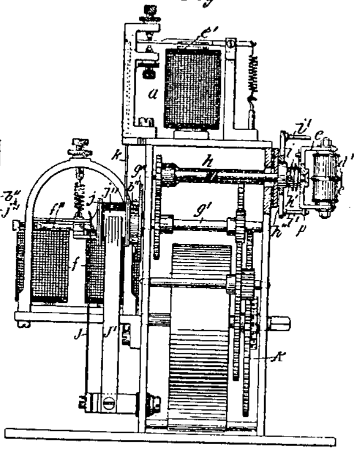


Fig. 4

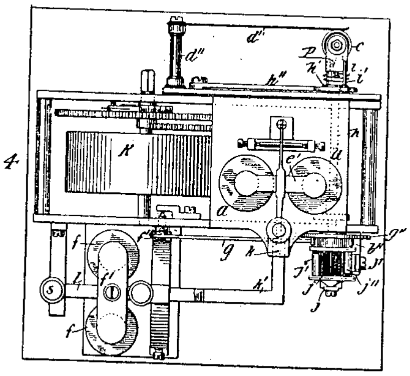
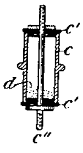


Fig. 8



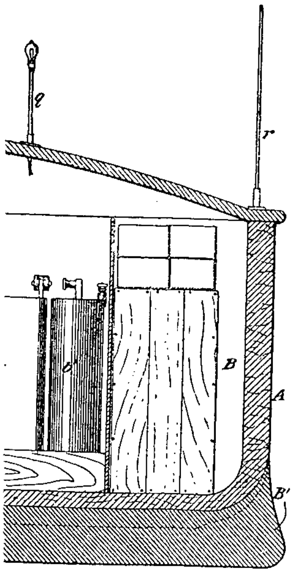
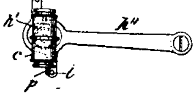


Fig. 7



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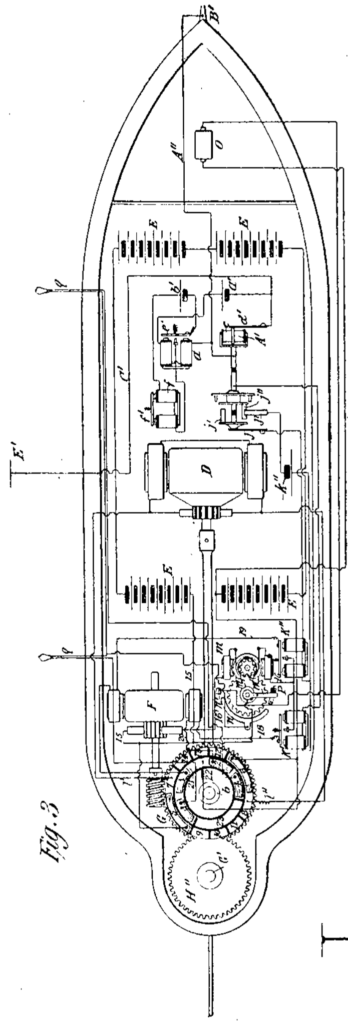

Fig. 3

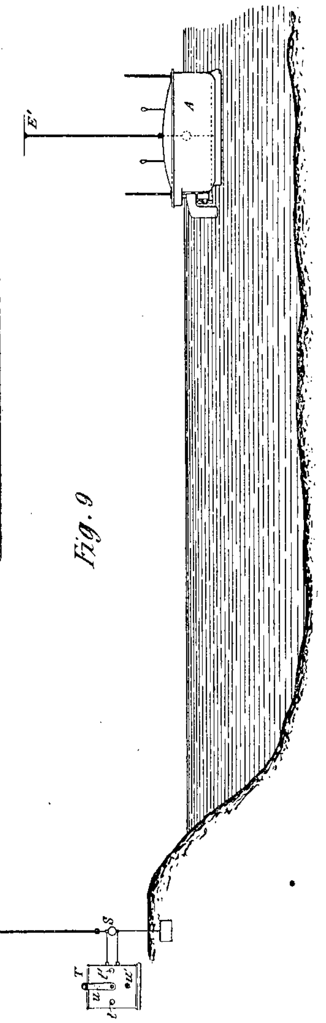

Fig. 9

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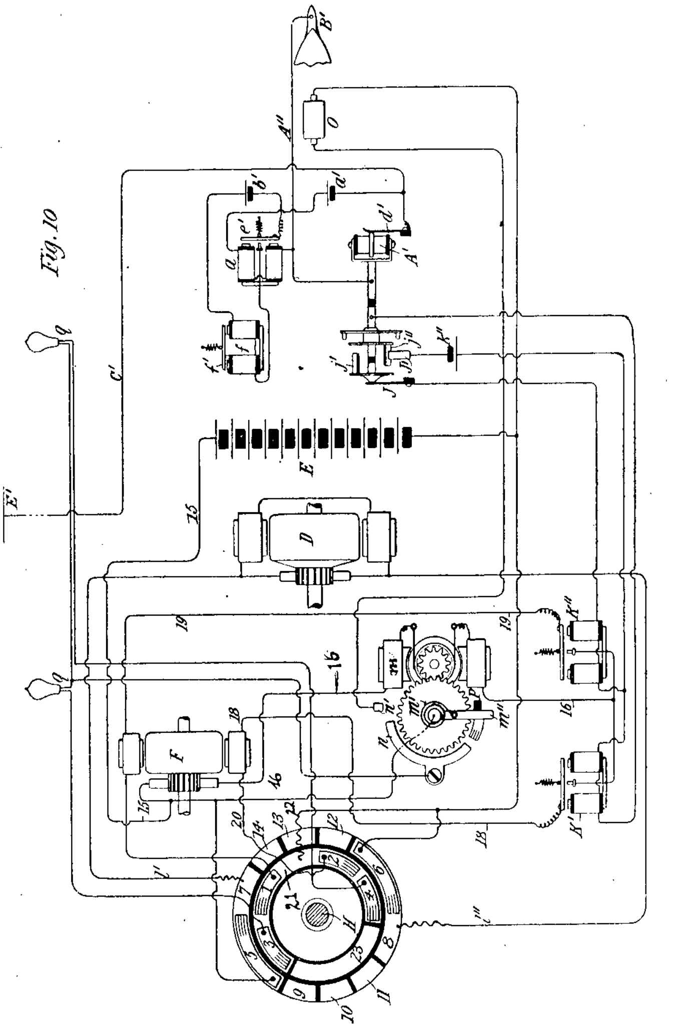
Fig. 10



Eigentum des
Kaiserlichen Patentamts.
Eingefügt der Sammlung
für Unterklasse
Gruppe Nr.

KAISERLICHES PATENTAMT.

AUSGEGEBEN DEN 1. AUGUST 1903.

PATENTSCHRIFT

— № 142842 —

KLASSE 65a. 2

18

NIKOLA TESLA IN NEW-YORK.

Vorrichtung zur Fernsteuerung von Wasserfahrzeugen mittels elektrischer Wellen.

Patentiert im Deutschen Reiche vom 8. November 1898 ab.

Gegenstand der vorliegenden Erfindung ist eine Vorrichtung zur Fernsteuerung von Wasserfahrzeugen mittels elektrischer Wellen, bei welcher auf der Fernsteuerungsstelle ein nur in einer Richtung drehbarer Stromschließer angeordnet ist, welcher bei einer vollen Umdrehung viermal während je einer kurzen Zeitdauer elektrische Schwingungen gleicher Art erzeugt, während auf dem zu steuernden Fahrzeug ein Uhrwerk sich befindet, welches unter Vermittelung einer für die elektrischen Wellen empfindlichen Vorrichtung bei jeder Schwingungsfolge für eine bestimmte Bewegung freigegeben wird und hierbei Stromkreise für Relais und Elektromotoren derart in bestimmter Folge schließt und öffnet, daß bei der ersten und bei der dritten Wellensendung das Steuerruder nach rechts bezw. nach links bewegt wird, während bei der zweiten und bei der vierten Wellensendung das Steuerruder in der bis dahin erreichten Stellung angehalten wird. Weiterhin gehören zum Bereiche der vorliegenden Erfindung besondere Ausführungsformen der bei dieser Fernsteuerungsvorrichtung verwendeten Empfangsvorrichtungen, die nachstehend eingehend beschrieben werden sollen.

In den beiliegenden Zeichnungen ist eine Ausführungsform der Vorrichtung zur Darstellung gebracht, und zwar ist

Fig. 1 ein Grundriß eines Schiffes mit der Steuerungseinrichtung gemäß der vorliegenden Erfindung,

Fig. 2 ein Längsschnitt dazu mit der Steuerungsvorrichtung in Seitenansicht.

Fig. 3 ist ein teilweise schematischer Grundriß dazu nebst Schaltung.

Fig. 4 ist ein Grundriß,

Fig. 5 eine Endansicht und

Fig. 6 eine Seitenansicht des Uhrwerks nebst zugehörigen Teilen in vergrößertem Maßstabe.

Fig. 7 zeigt die für die elektrischen Wellen empfindliche Vorrichtung (Fritter) in Seitenansicht,

Fig. 8 im Schnitt und in vergrößertem Maßstabe.

Fig. 9 gibt eine schematische Darstellung der Steuerungsstelle nebst Abbildung des Fahrzeuges.

Fig. 10 ist eine schematische Ansicht der Stromkreise und Mechanismen in größerem Maßstabe, wobei einzelne bekannte Teile fortgelassen oder durch übliche Zeichen angedeutet sind.

In Fig. 1 und 2 bezeichnet *A* das zu steuernde Fahrzeug, welches in einem Abteil *B* Gegenstände irgend welcher Art, je nach seiner Bestimmung, enthalten kann. Dieses Fahrzeug ist mit einer geeigneten Treibvorrichtung, etwa einer Schraube *C* auf der Welle eines Elektromotors *D* ausgestattet, der den Betriebsstrom den Sammelbatterien *E E E E* entnimmt.

Außer der Treibmaschine besitzt das Boot noch eine kleinere Steuermaschine *F*, deren Welle über die Lager hinaus verlängert ist und eine Schnecke trägt, die in ein Zahnrad *G* eingreift. Das letztere ist an einer auf der senkrechten Stange *H* frei beweglichen Hülse *b* befestigt und wird je nach der Drehungsrichtung des Motors F in der einen oder der anderen Richtung gedreht. Die Hülse b auf der Stange H ist durch Zahnräder H' und H'' mit einer Welle G' gekuppelt, die in senkrechten Lagern am Achtersteven angeordnet ist und das Steuerruder F' trägt.

Die Einrichtung, mittels deren die Steuermaschine beherrscht wird, umfaßt zunächst eine Empfangsleitung, die auf die Wellen abgestimmt ist, welche von einer entfernten Station ausgesendet werden. Es kann dies entweder derart geschehen, daß ihre Schwingungszahl gleich der Schwingungszahl der ausgesendeten Wellen gemacht ist, oder daß beide in einem harmonischen Verhältnis zueinander stehen. Die eigentliche Empfangsleitung, die in Fig. 3 und 10 schematisch dargestellt ist, besteht aus dem Endpol E', dem Leiter C', der für die elektrischen Wellen empfindlichen Vorrichtung (dem Fritter) A' und einem Leiter A'', der zur Erde führt, indem er etwa mit dem metallenen Kiel B' des Schiffes verbunden ist. Der Endpol E' sollte eine größere leitende Oberfläche besitzen und so hoch als möglich auf einem Ständer D', der in Fig. 2 abgebrochen dargestellt ist, angeordnet sein, doch ist eine derartige Einrichtung nicht immer nötig. Der Leiter C' ist in jedem Falle sorgfältig zu isolieren.

Die eben erwähnte Leitung bildet auch einen Teil einer Ortsleitung, die ein Relais a und eine Batterie a' enthält, deren elektromotorische Kraft so bemessen ist, daß vermöge der dielektrischen Schichten in der für die elektrischen Wellen empfindlichen Vorrichtung A' kein merklicher Strom durch die Ortsleitung fließt. Wenn aber elektrische Störungen die Leitung erreichen, erfährt der Widerstand der für die elektrischen Wellen empfindlichen Vorrichtung A' eine plötzliche starke Abnahme und ein Strom geht durch das Relais a. Die für die elektrischen Wellen empfindliche Vorrichtung ist in Fig. 4, 6, 7 und 8 dargestellt. Sie besteht aus einem Metallzylinder c mit isolierenden Deckeln c', durch welche eine Metallstange c'' hindurchgeht. In dem Zylinder befindet sich eine geringe Menge von Körnern eines leitenden Materials d, etwa aus oxydiertem Metall. Ein Metallstreifen d', der an einem Ständer d'' befestigt ist (s. Fig. 4), liegt an der Seite des Zylinders c und verbindet denselben mit dem Leiter C' der Leitung. Die Stange c'' ist mit dem Apparatgestell und daher mit dem anderen Teil der Leitung durch den gegabelten metallenen Arm e verbunden, dessen Enden durch zwei Muttern an den vorspringenden Enden der Stange befestigt sind. Hierdurch wird der Zylinder c unterstützt. Um den Batteriestrom, der beim Ansprechen der für die elektrischen Wellen empfindlichen Vorrichtung A' auftritt, zu unterbrechen, sind folgende Einrichtungen getroffen. Der Anker e' des Elektromagneten a schließt, wenn er von letzterem angezogen wird, eine Ortsleitung, die die Batterie b' und den Elektromagneten f enthält; der Anker f' der letzteren ist an einer Drehwelle f'' (Fig. 4, 5 und 6) befestigt, auf der der Steigradanker g sitzt, der die Bewegung einer von einem Uhrwerk K getriebenen Achse g' beherrscht. An der Welle g' ist eine Scheibe g'' mit vier Stiften b'' befestigt, so daß bei jeder Schwingung des Steigradankers g die Welle g' eine Viertelumdrehung macht. Eine der Wellen des Uhrwerks, etwa h, macht eine halbe Umdrehung bei jeder Viertelumdrehung der Welle g'. Das Ende der ersteren Welle reicht durch die Seite des Gestelles hinaus und trägt einen exzentrischen Zylinder h', der durch einen Schlitz in einem Hebel h'' an der Seite des Gestelles hindurchgeht. Der gegabelte Arm e, welcher den Zylinder c trägt, ist am Ende des Exzenters h' eingelenkt, und das Exzenter und der Arm sind durch eine Spiralfeder i verbunden. Zwei Stifte i' i' ragen aus dem Hebel h'' heraus, und einer derselben ist stets in der Bahn eines Ansatzes p am Arm e. Diese Stifte verhindern die Drehung des Zylinders c mit der Welle h und dem Exzenter. Es ist klar, daß eine halbe Umdrehung der Welle h die Feder i spannt und zugleich den Hebel h'' hebt oder senkt. Diese Teile sind so angeordnet, daß gerade, bevor die halbe Umdrehung der Welle beendigt ist, der Stift i, der mit dem Anschlagstift p in Eingriff steht, zurückgezogen wird, und der Zylinder c, der Feder i folgend, plötzlich um die Querachse um 180° gedreht wird. Die Bewegung desselben wird durch den anderen Stift i' aufgehalten. Die Einstellung gegenüber dem Anker f' oder dem Magnet f ist ferner eine derartige, daß der Stift i' in dem Augenblick zurückgezogen wird, wenn der Anker vom Magneten nahezu vollständig angezogen worden ist, d. h. wenn der Hebel l, welcher den Anker f' trägt, den unteren der beiden Anschläge $s\,s$ (Fig. 5), welche seine Bewegung in beiden Richtungen begrenzen, nahezu erreicht hat.

Der Zylinder c steht für gewöhnlich senkrecht, und wenn er in der beschriebenen Weise gedreht wird, so werden die oxydierten Metallkörner in demselben einfach von einem Ende an das andere gelangen. Da nun die Körner dabei stets durch dieselbe Strecke fallen und in gleicher Weise bewegt werden, so werden sie nach jeder Bewegung des Relais in genau denselben elektrischen Zustand zurückkehren und dem Batteriestrom denselben Widerstand entgegensetzen, bis ein anderer aus der Ferne kommender Impuls die Empfangsleitung erreicht.

Das Relais a muß auf einen sehr schwachen

Strom ansprechen, dabei aber durchaus sicher arbeiten. Um das Abreißen des Ankers e' zu sichern, nachdem ein Strom durch den Elektromagneten f gesendet und durch die Umkehrung der für die elektrischen Wellen empfindlichen Vorrichtung c wieder unterbrochen worden ist, ist eine leichte Stange k in Führungen am Gestell in einer solchen Lage angebracht, daß sie durch einen Ansatz k' des Ankerhebels l gehoben wird und den Anker e' etwas hebt. Da für gewöhnlich ein sehr schwacher Strom durch die für die elektrischen Wellen empfindliche Vorrichtung und das Relais a fließen könnte, der die Relaiszunge zwar nicht anziehen, aber doch festzuhalten vermöchte, so ist diese Vorsichtsmaßregel dringend geboten. Die Wirkung des Relais a und die hierdurch eingeleitete Wirkung des Elektromagneten f, wie sie vorstehend beschrieben wurden, wird zur Beherrschung der Steuerungsvorrichtung in der folgenden Weise benutzt.

Auf der Welle g', welche das Steigrad g'' trägt (Fig. 4, 5 und 6), sitzt ein Zylinder j aus isolierendem Material mit einer leitenden Platte an jedem Ende. Aus diesen Platten ragen an einander diametral gegenüberliegenden Stellen des Zylinders Kontaktplatten $j' j''$ heraus, von denen letztere durch die Platte, aus welcher sie herausragt, mit dem Apparatgestell in leitender Verbindung steht, während isolierte Streifen oder Bürsten $J J'$ am freien Ende des Zylinders bezw. am Umfang desselben anliegen. Es entstehen so drei Pole, von denen der eine dauernd mit der Platte j', der zweite mit der Platte j'' verbunden ist, während der dritte je nach der Stellung, in welche der Umschalter durch das Schaltwerk g gebracht wird, mit dem einen oder dem anderen Streifen $j' j''$ verbunden ist, oder endlich durch Aufliegen der Kontaktfeder auf den isolierenden Teilen des Zylinders isoliert ist. $K' K''$ (Fig. 1, 3 und 10) sind zwei Relais hinter der Treibmaschine. Ein Pol einer Batterie k'' ist mit einer Klemme jeder der Relaisspulen und der andere mit der Bürste J' verbunden, während die anderen Klemmen der Relaisspulen mit der Bürste J und dem Apparatgestell verbunden sind.

Bei dieser Anordnung wird entweder das eine oder das andere Relais K' oder K'' zum Ansprechen gebracht, wenn die Bürste J' auf den Platten j' bezw. j'' liegt, oder es sind beide Relais außer Tätigkeit, wenn die Bürste J' auf der Isolierung zwischen j' und j'' aufliegt. Spricht nun eines der Relais, etwa K' an, so stellt sein Anker eine Schließung durch den Motor F her, welcher dann in einer Richtung in Bewegung gesetzt wird, um das Steuerruder backbords zu drehen. Spricht dagegen das Relais K'' an, so wird eine andere Schließung durch den Motor F hergestellt, wodurch die Bewegungsrichtung des letzteren umgekehrt und das Steuerruder steuerbords gedreht wird. Diese Schließungen dienen aber gleichzeitig auch zu anderen Zwecken und führen deshalb auch durch andere sogleich zu beschreibende Apparate.

Die feste Stange H trägt eine isolierende Scheibe L (Fig. 2), an deren Unterseite sechs Bürsten 1, 2, 3, 4, 5, 6 (Fig. 3) befestigt sind. Die Hülse b, welche auf die Stange aufgeschoben ist und durch den Steuerungsmotor F gedreht wird, trägt eine Scheibe L', auf deren oberer Fläche sich zwei konzentrische Kreise von Kontaktsegmenten befinden. Die Bürsten 1, 2, 3 und 4 liegen auf dem inneren Kreis von Kontaktsegmenten, die Bürsten 5 und 6 dagegen auf dem äußeren. Der äußere Kreis von Kontaktsegmenten besteht aus zwei langen Segmenten 7 und 8 auf einander gegenüberliegenden Stellen der Platte und aus einer Reihe von kurzen Segmenten 9, 10, 11, 12, 13, 14 zwischen den langen Segmenten. Biegsame Leiter $l' l''$ verbinden die Segmente 7 und 8 mit den Klemmen der Treibmaschine D, und die Pole der Batterie E sind mit den Bürsten 5 und 6 verbunden, so daß, während das Ruder mittschiffs steht oder nach einer Seite gedreht wird, der Strom durch die Bürsten 5 und 6 und die Segmente 7 und 8 zur Treibmaschine D fließt.

Der Steuerungsmotor F wird auch durch einen der Batterie E entnommenen Strom getrieben. Ein Leiter 15 führt von einem Pol der Hauptbatterie E zu einer der Stromsammelbürsten, und von der anderen Bürste geht ein Leiter 16 zu den Kontakten, welche von den beiden Relais $K' K''$ geschlossen werden. Ist eines der letzteren, etwa K'', in Tätigkeit, so geht die Leitung weiter durch den Draht 19 und einen Feldmagnetspulensatz des Motors F zur Bürste 1; ist aber das Relais K' in Tätigkeit, so setzt sich die Leitung durch den Draht 18, einen zweiten Feldmagnetspulensatz und den Draht 20 zur Bürste 2 fort. So lange das Steuerruder um nicht mehr als 45° auf eine Seite gedreht ist, liegen die Bürsten 1 und 2 stets auf einem langen Segment 21, und eine Bürste liegt bei jeder Stellung des Ruders auf diesem Kontaktsegment, das durch einen biegsamen Leiter 22 (Fig. 3 und 10) mit dem anderen Pol der Hauptbatterie verbunden ist. Der Motor F kann daher stets in einer Richtung getrieben werden, gleichgültig, welche Stellung das Steuerruder einnimmt, und kann stets in beiden Richtungen getrieben werden, wenn das Steuerruder einen Winkel mit dem Kiel bildet, der kleiner ist als ein festgesetzter Winkel, z. B. 45°.

Um indessen zu verhindern, daß das Steuerruder in der einen oder in der anderen Richtung zu weit gedreht wird, wird die isolierte Platte 23 benutzt. Jede Bewegung des Steuerruders über eine bestimmte Grenze hinaus bringt diese Platte 23 unter die eine oder die andere der Bürsten 1, 2 und unterbricht den Stromkreis des Motors F, so daß das Ruder in dieser Richtung nicht weiter gedreht werden kann; wohl aber kann das Ruder in der entgegengesetzten Richtung gedreht werden. In gleicher Weise wird der Stromkreis der Treibmaschine D durch Bürsten 5 und 6 und die Segmente des äußeren Kontaktringes auf der Scheibe L beherrscht. Wenn die kurzen Segmente 9, 10, 11, 12, 13, 14 auf beiden Seiten des Kreises isoliert sind, so wird der Motor D angehalten, wenn eine der Bürsten 5 oder 6, von einem der langen Segmente 7 und 8 kommend, auf eines der kurzen Segmente aufläuft. Die kurzen Segmente können untereinander oder mit den langen Segmenten in verschiedener Weise verbunden sein, um die Stärke des durch den Motor D fließenden Stromes zu beeinflussen, wenn eine der Bürsten 5 oder 6 auf einem derselben aufliegt; um aber die Zeichnung nicht zu verwirren, sind derartige Verbindungen nicht dargestellt, da sie sich ja dem Fachmann von selbst darbieten.

Es ist von Wichtigkeit, hier noch hinzuzufügen, daß an allen Kontaktstellen, an denen eine Unterbrechung des Stromes vorkommt, Vorkehrungen zu treffen sind, um Funkenbildung und wellenförmige Entladungen in den Leitungen zu verhindern, da diese die für die elektrischen Wellen empfindliche Vorrichtung beeinflussen könnten. Diese Erwägung läßt es rätlich erscheinen, die beiden Relais $K' K''$ zu benutzen, welche sonst entbehrlich wären. Sie sollten auch soweit als möglich von der für die elektrischen Wellen empfindlichen Vorrichtung aufgestellt sein, um die letztere gegen die Einwirkung starker veränderlicher Ströme zu schützen.

Außer den beschriebenen Vorrichtungen kann das Schiff noch andere Vorrichtungen tragen, welche zur Erreichung besonderer, mehr oder minder wichtiger Zwecke nötig sind. Beispielsweise ist ein kleiner Motor m (Fig. 1, 3 und 10) dargestellt, welcher eine Anzahl von Aufgaben zu erfüllen hat. Dieser Motor ist in Reihenschaltung mit dem Anker des Steuerungsmotors F verbunden, so daß, wenn der eine oder der andere Stromkreis des letzteren durch die Relais $K' K''$ geschlossen ist, auch der Motor m läuft, aber stets nur in derselben Richtung. Der Drehung dieses Motors wirkt eine Feder m' entgegen, so daß beim gewöhnlichen Betrieb, wo der Stromkreis des Motors F nur für kurze Zeit geschlossen ist, der Hebel m'', der an einem der Räder des Getriebes M befestigt ist, mit welchem der Anker des Motors gekuppelt ist, sich nur ein kleines Stück bewegt und beim Aufhören des Stromes unter der Wirkung der Feder m', welche den Motor wieder rückwärts dreht, an einen Anschlag P zurückkehrt. Wenn aber der Stromkreis des Motors F rasch nacheinander hergestellt und unterbrochen wird, wobei das Steuerruder unbeeinflußt bleibt, so wird der Hebel m'' um einen größeren Winkel gedreht und kommt mit einer Metallplatte n und schließlich, wenn gewünscht, mit einem Kontakt n' in Berührung. Wenn der Hebel m'' auf die Platte n aufläuft, so fließt der Strom der Hauptbatterie entweder durch das eine oder das andere oder durch beide Lichter auf den Ständern $q\,q$, je nach der Stellung der Bürsten 3 und 4 gegenüber dem isolierenden Segment 23. Da aber die Scheibe L, welche die Segmente trägt, mit dem Ruder gekuppelt ist, so läßt sich die Stellung des letzteren durch Beobachtung der Lichter erkennen. Beide Lichter können gefärbt sein, und durch Aufleuchtenlassen derselben zu gewünschten Zeiten ist man imstande, den Bewegungen des Schiffes bei Nacht zu folgen. Zu diesem Zweck sind auch die Ständer $r\,r$ vorgesehen, welche mit lebhaften Farben angestrichen sind, um sie bei Tage auf große Entfernungen wahrnehmen zu können.

Wird das aufeinander folgende Öffnen und Schließen der Leitungen des Motors F hinreichend oft, am besten eine gegebene Anzahl von Malen, wiederholt, so legt sich der Hebel m'' auf den Kontakt n', wodurch die Hauptbatterie durch eine Vorrichtung o geschlossen und letztere in dem gewünschten Augenblick in Tätigkeit gesetzt wird. Durch ähnliche Einrichtungen oder andere, sich dem Sachverständigen von selbst darbietende, kann man eine beliebige Anzahl von Vorrichtungen auslösen.

In Fig. 9 ist schematisch die Vorrichtung auf der Steuerungsstelle an Land dargestellt. Es ist S eine Quelle elektrischer Schwingungen oder Störungen, deren Erzeugung durch einen geeigneten Stromschließer im Kasten T beherrscht wird. Der Griff dieses Stromschließers ist bloß in einer Richtung beweglich und vermag auf vier Punkten $t\,t'\,u\,u'$ stehen zu bleiben, so daß, wenn der Griff von einem dieser Punkte zum anderen bewegt wird, während einer sehr kurzen Zeit Schwingungen erzeugt werden. Es werden so während einer Umdrehung vier derartige Störungen hervorgerufen und die Empfangsleitung wird viermal beeinflußt. Aus der vorstehenden Beschreibung der Beherrschungsvorrichtung am Schiff erkennt man nun, daß das Steuerruder zweimal bewegt wird, einmal nach rechts und einmal nach links; den Griff des Stromschließers stellt man nun am besten so ein, daß, wenn er an den Punkten $t\,t'$ angehalten wird, d. h. rechts oder links von der den Apparaten bedienenden Person, das Schiff nach rechts oder links von seinem Kurs abgelenkt wird. Hierdurch wird der Betrieb erleichtert. Die gewöhnlichen Lagen des Griffes sind deshalb auf u oder u', wo das Steuerruder nicht beeinflußt wird, und der Griff bleibt auf den anderen Punkten $t\,t'$ nur so lange als nötig ist.

Die Art der Anwendung des Apparats und die Wirkungsweise der einzelnen Vorrichtungen, welche derselbe umfaßt, sind folgende:

Für gewöhnlich ist die Platte L' so gestellt, daß die Bürste 2 auf dem isolierten Segment 23 und die Bürste 6 auf den isolierten kurzen Segmenten aufliegt. Unter diesen Umständen ist das Ruder steuerbords gedreht, und der Stromkreis des Motors D ist an den Bürsten 5 und 6 unterbrochen. Gleichzeitig kann nur eine der Schaltungen des Motors F, nämlich jene, die vom Relais K'' beherrscht wird, geschlossen werden, da die Bürste 2, welche mit dem anderen Relais K' verbunden ist, außer Berührung mit dem langen Segment 21 steht. Es soll nun das Schiff gegen einen gegebenen Punkt in Bewegung gesetzt werden. Der Griff T wird aus seiner gewöhnlichen Lage, in der er auf dem Punkt u' liegt, auf den Punkt t des Umschalterkastens gestellt. Hierdurch wird eine elektrische Störung ausgesendet, welche, wenn sie in der Empfangsleitung am Schiff anlangt, die für die elektrischen Wellen empfindliche Vorrichtung A' leitend macht; infolgedessen fließt ein Strom durch die Ortsleitung, welche diese Vorrichtung, das Relais a und die Batterie a' enthält. Hierdurch wird, wie erwähnt, der Zylinder j gedreht, und die Bürste J' verläßt die Isolation und läuft auf den Kontakt j' auf. Dieser Kontakt und die Batterie k'' stellen dann den Stromkreis des Motors F her. Der letztere geht von der dauernd mit einem Pol der Hauptbatterie verbundenen Platte 22 aus durch die Bürste 1, den Feldmagneten von F, den Draht 19, den Anker des Relais K'', den Draht 16, den Motor m, die Bürsten und den Stromsammler von F und den Draht 15 zum anderen Pol der Batterie E. Der Motor F wird hierdurch in Tätigkeit gesetzt, um das Steuerruder backbords zu drehen; dabei wird die Platte L' zurückbewegt, das Segment 8 kommt unter die Bürste 6 und stellt den Stromkreis der Treibmaschine D her, welche das Schiff in Bewegung setzt. Der Motor F wird so lange laufen gelassen, bis das Ruder hinreichend weit gedreht worden ist, um das Schiff in der gewünschten Richtung zu steuern, worauf der Griff auf u gestellt wird. Hierdurch wird das Relais a abermals zum Ansprechen gebracht, und die Bürste J' gelangt auf die Isolation und beide Relais $K'\,K''$ sind außer Tätigkeit.

Das Steuerruder bleibt in der Stellung, in welche es durch den Motor F gebracht wurde. Will man es dann steuerbords oder entgegengesetzt zur früheren Richtung drehen, so wird der Griff T einfach auf den Punkt t' gebracht und dort liegen gelassen, bis der Motor F, der nun unter der Einwirkung des Relais K' steht, das durch Auflaufen von J' auf j'' eingeschaltet worden ist, seine Arbeit verrichtet hat. Die Bewegung des Griffes T auf den nächsten Punkt schaltet beide Relais K' und K'' aus, und die nächste Bewegung bewirkt eine Drehung des Ruders backbords usf. Nimmt man aber an, daß, nachdem das Ruder unter einem bestimmten Winkel gegen die Mittellage eingestellt worden ist, es noch weiter in derselben Richtung gedreht werden soll, so wird der Griff rasch über zwei Punkte bewegt, so daß der Stromkreis, welcher die Bewegung des Ruders in der entgegengesetzten Richtung bewirken würde, viel zu kurze Zeit geschlossen ist, um eine merkliche Wirkung hervorzurufen; der Griff wird also erst auf dem dritten Punkte liegen gelassen, und zwar so lange, bis das Steuerruder in die gewünschte Richtung gebracht worden ist; der Griff wird dann auf den nächsten Punkt gestellt, wodurch die Relais $K'\,K''$ abermals ausgeschaltet werden. Man erkennt, daß, wenn der Griff hinreichend lange Zeit auf dem einen oder dem anderen Punkt t oder t' gehalten wird, der Motor F die Platte L' einfach in der einen oder der anderen Richtung dreht, bis die Stromkreise der Motoren D und F unterbrochen sind; es ist ferner klar, daß ein Relais K' oder K'' stets bereit ist, den Motor F in Bewegung zu setzen.

Wie vorhin bemerkt, ist die längste Dauer der Wirkung des Motors F unter gewöhnlichen Betriebsbedingungen nicht ausreichend, um dem Motor m zu gestatten, den Am m' auf die Platte n zu schieben. Wenn aber der Griff T mit einer gewissen Geschwindigkeit gedreht wird, so geht eine Reihe von Stromstößen durch den Motor m, welche das Bestreben haben, den Motor F in aufeinanderfolgend entgegengesetzten Richtungen zu drehen und daher auf diesen Motor eine merkliche Wirkung nicht ausüben; dagegen wirken diese Ströme dahin, den Motor m gegen die Wirkung der Spiralfeder zu drehen.

PATENT-ANSPRÜCHE:

1. Eine Vorrichtung zur Fernsteuerung von Wasserfahrzeugen mittels elektrischer Wellen, dadurch gekennzeichnet, daß auf der Fernsteuerungsstelle ein nur in einer Richtung drehbarer Stromschließer angeordnet ist, welcher bei einer vollen Umdrehung viermal während je einer kurzen Zeitdauer elektrische Schwingungen gleicher Art erzeugt, während auf dem zu steuernden Fahrzeug ein Uhrwerk sich befindet,

welches unter Vermittelung einer für die elektrischen Wellen empfindlichen Vorrichtung bei jeder Schwingungsfolge für eine bestimmte Bewegung freigegeben wird und hierbei Stromkreise für Relais und Elektromotoren derart in bestimmter Folge schließt und öffnet, daß bei der ersten und bei der dritten Wellensendung das Steuerruder nach rechts bezw. nach links bewegt wird, während bei der zweiten und bei der vierten Wellensendung das Steuerruder in der bis dahin erreichten Stellung angehalten wird.

2. Eine weitere Ausbildung der Empfangsvorrichtung auf dem Fahrzeug, dadurch gekennzeichnet, daß auf einer zugleich mit dem Steuerruder gedrehten Scheibe *(L')* kreisbogenförmige Kontaktstücke angeordnet sind, welche mit feststehenden Kontaktfedern derart in Berührung stehen, daß bei Erreichung eines bestimmten maximalen Ausschlages des Steuerruders nach links oder rechts der zugehörige Motorstromkreis unterbrochen, das Steuerruder also selbsttätig angehalten wird, während jeweilig der Stromkreis für die entgegengesetzte Bewegung des Motors geschlossen bleibt.

3. Eine weitere Ausbildung der Empfangsvorrichtung auf dem Fahrzeug, dadurch gekennzeichnet, daß der Fritter mit einer quer zu seiner Längsachse gerichteten horizontalen Achse des Uhrwerks derart unter Zwischenschaltung einer Feder verbunden ist, daß der Fritter nach der Freigabe des Uhrwerks zunächst in Ruhe bleibt und erst gegen Ende der Bewegung des Uhrwerks plötzlich um eine halbe Umdrehung bewegt und somit entfrittet wird.

4. Eine weitere Ausbildung der Empfangsvorrichtung auf dem Fahrzeug, dadurch gekennzeichnet, daß mit dem Anker des Antriebsmotors für das Steuerruder ein Hülfsmotor *(m)* in Reihe geschaltet ist, dessen Ankerwelle derart unter der Wirkung einer Feder steht, daß der Anker nur bei rasch aufeinander folgenden Wellensendungen gedreht wird und dabei Stromkreise für verschieden gefärbte Lichter zur Sichtbarmachung der jeweiligen Lage des Steuerruders bei Nacht einschaltet.

Hierzu 1 Blatt Zeichnungen.

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI.

NIKOLA TESLA in NEW-YORK.

Vorrichtung zur Fernsteuerung von Wasserfahrzeugen mittels elektrischer Wellen.

Fig. 1.

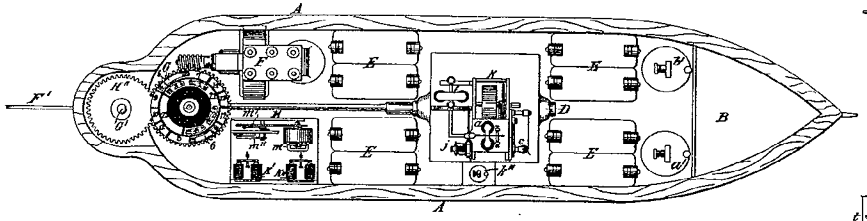


Fig. 2

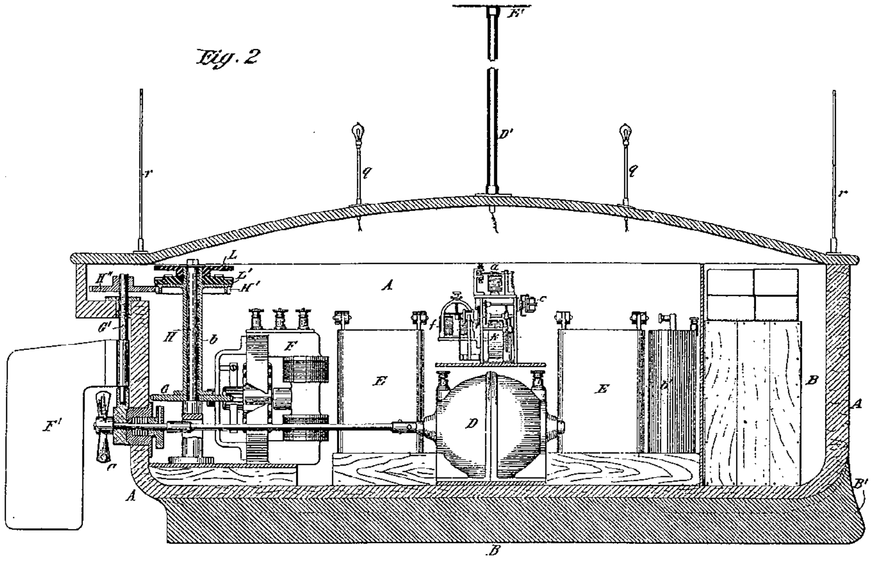


Fig. 3

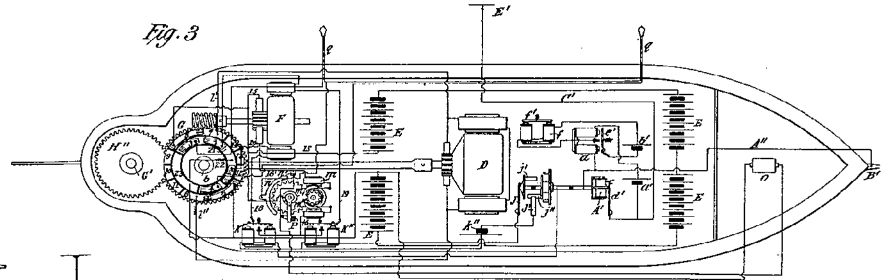


Fig. 9

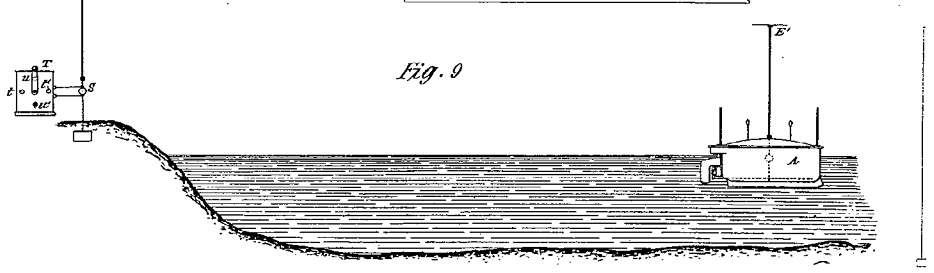
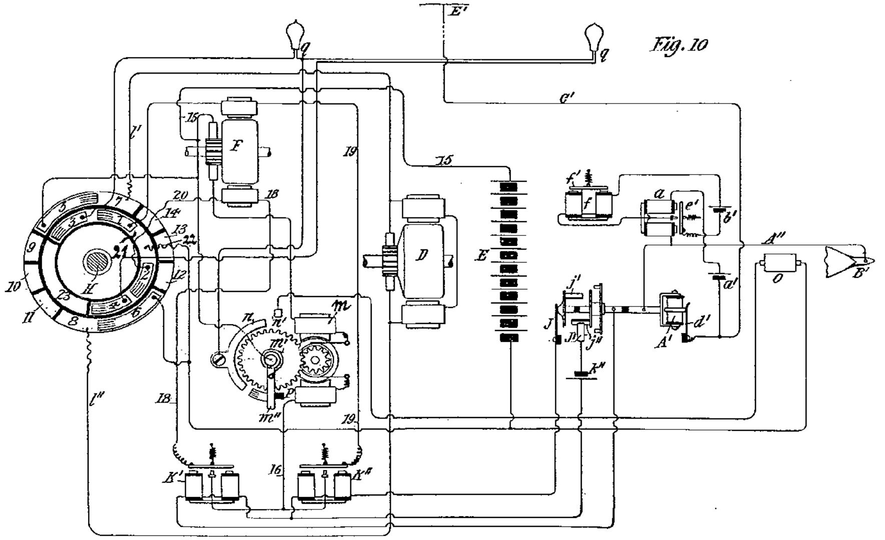


Fig. 10

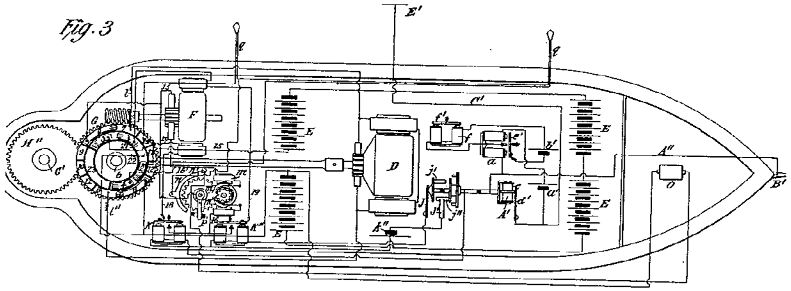


PHOTOGR. DRUCK DER REICHSDRUCKEREI.

NIKOLA TESLA in NEW-YORK.

zur Fernsteuerung von Wasserfahrzeugen mittels elektrischer Wellen.

Fig. 3



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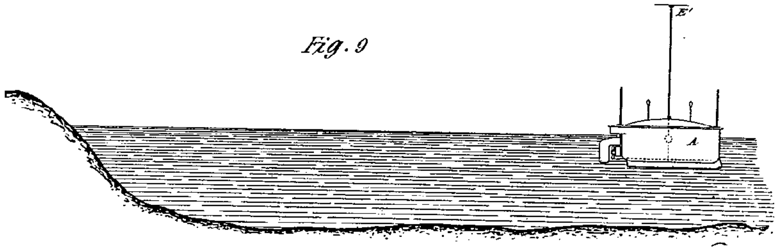
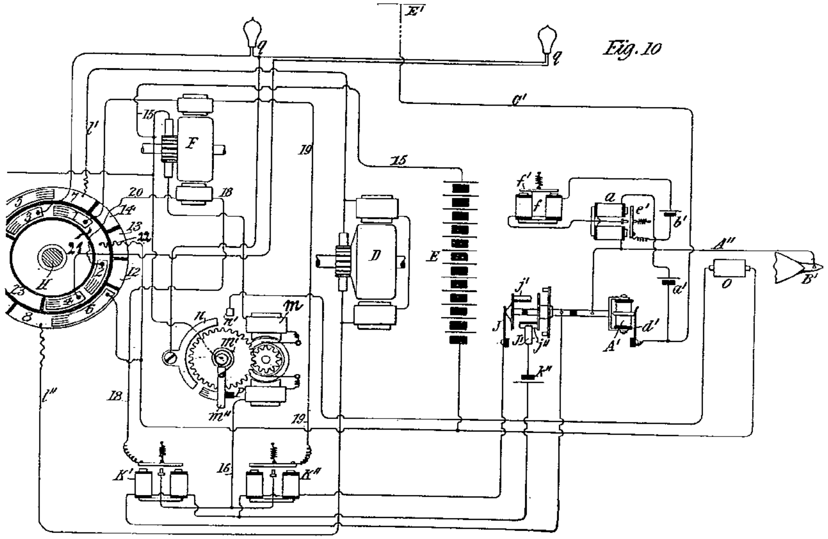


Fig. 10



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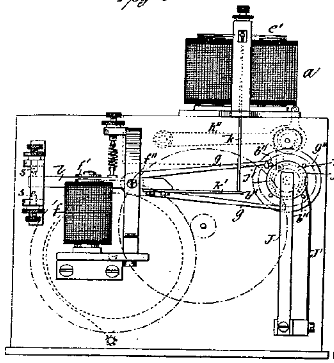

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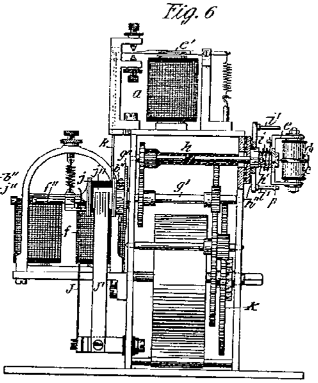

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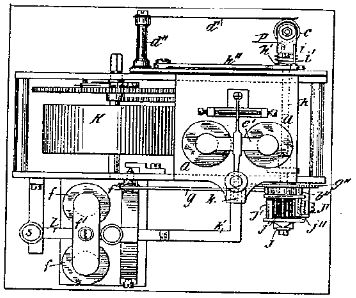

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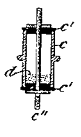
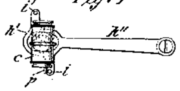


Fig. 7



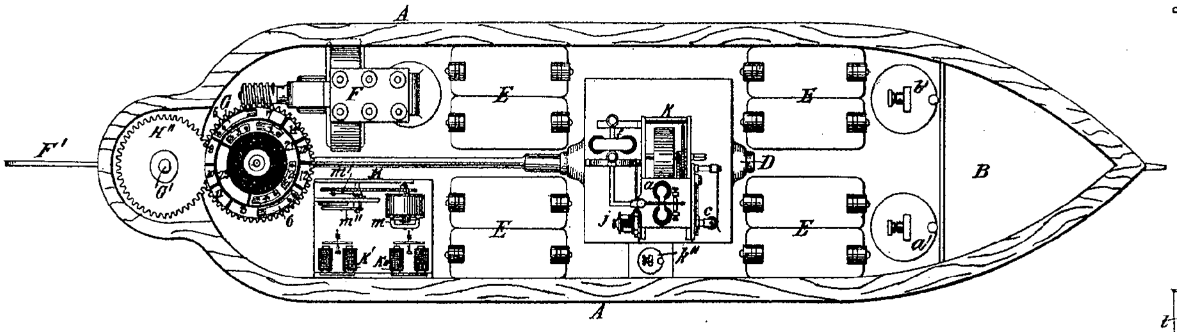
PHOTOGR. DRUCK DER REICHSDRUCKEREI.

Zu der Patentschrift

№ 142842.

Vorrichtung

Fig. 1



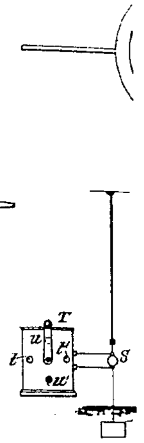
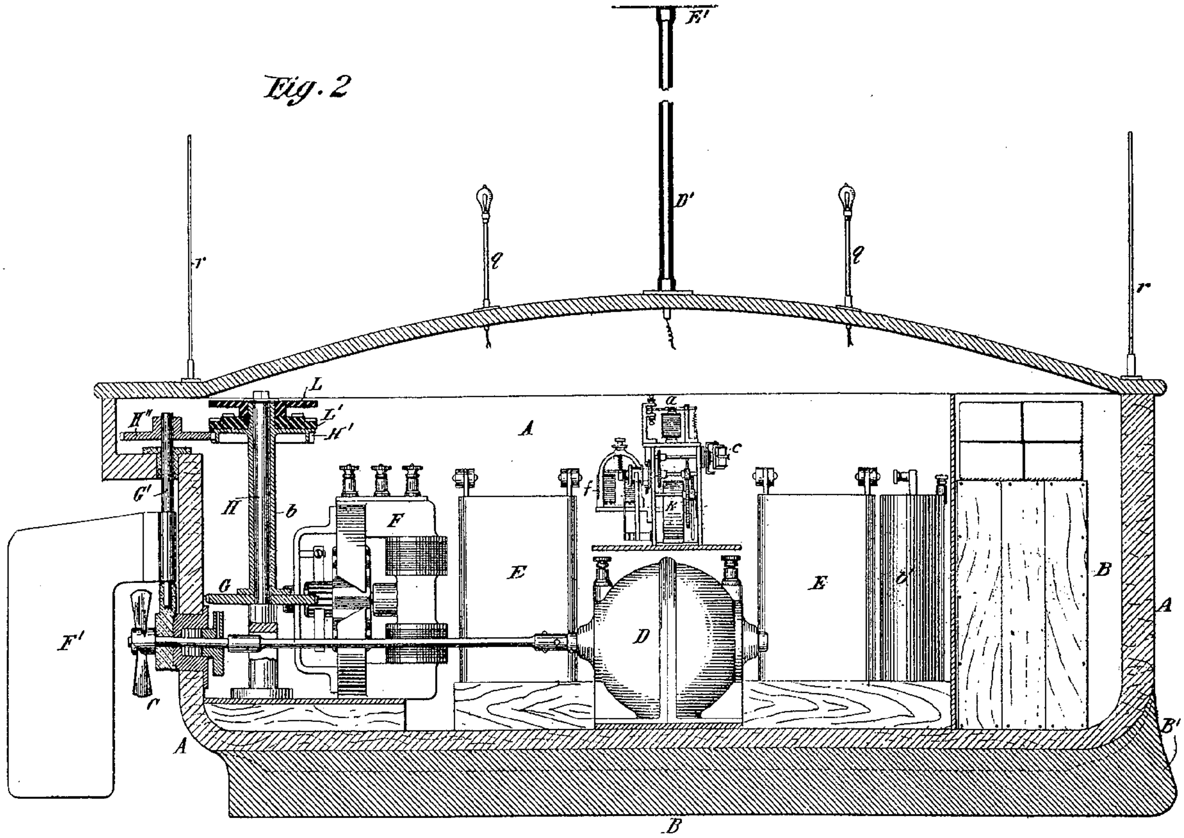


Fig. 2



NIKOLA TESLA IN NEW-YORK.

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Fig. 3

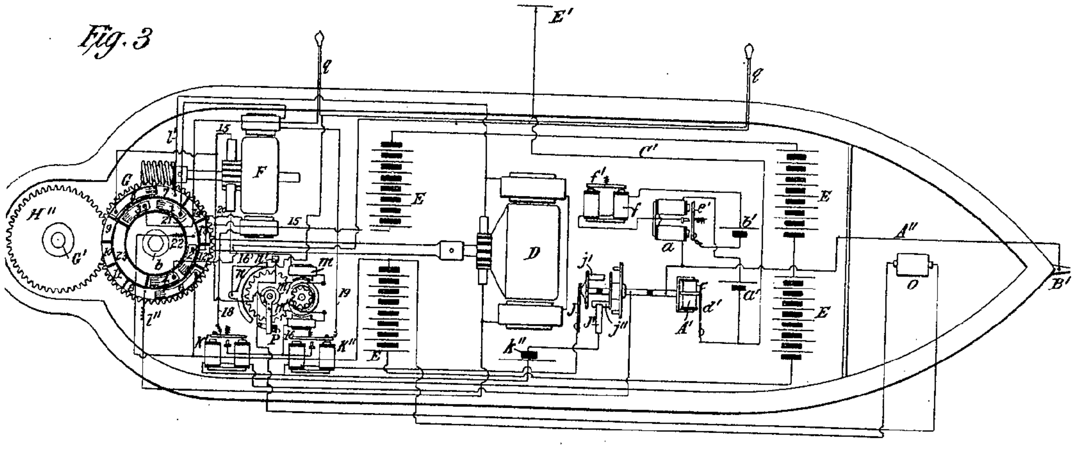
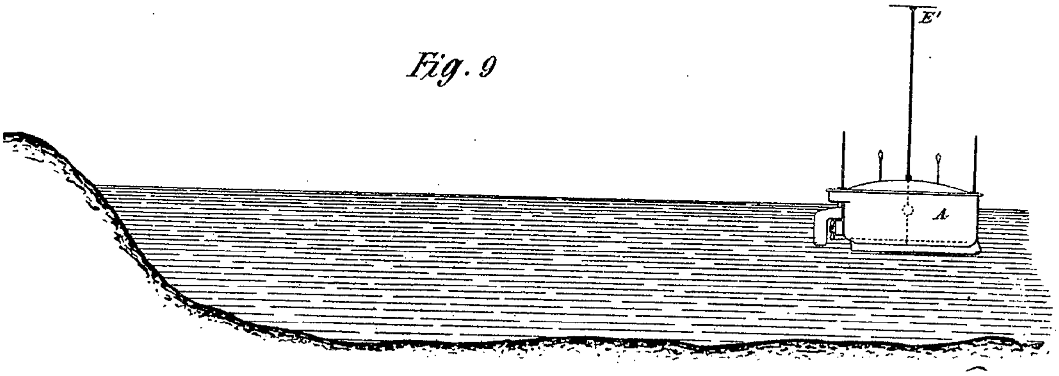


Fig. 9



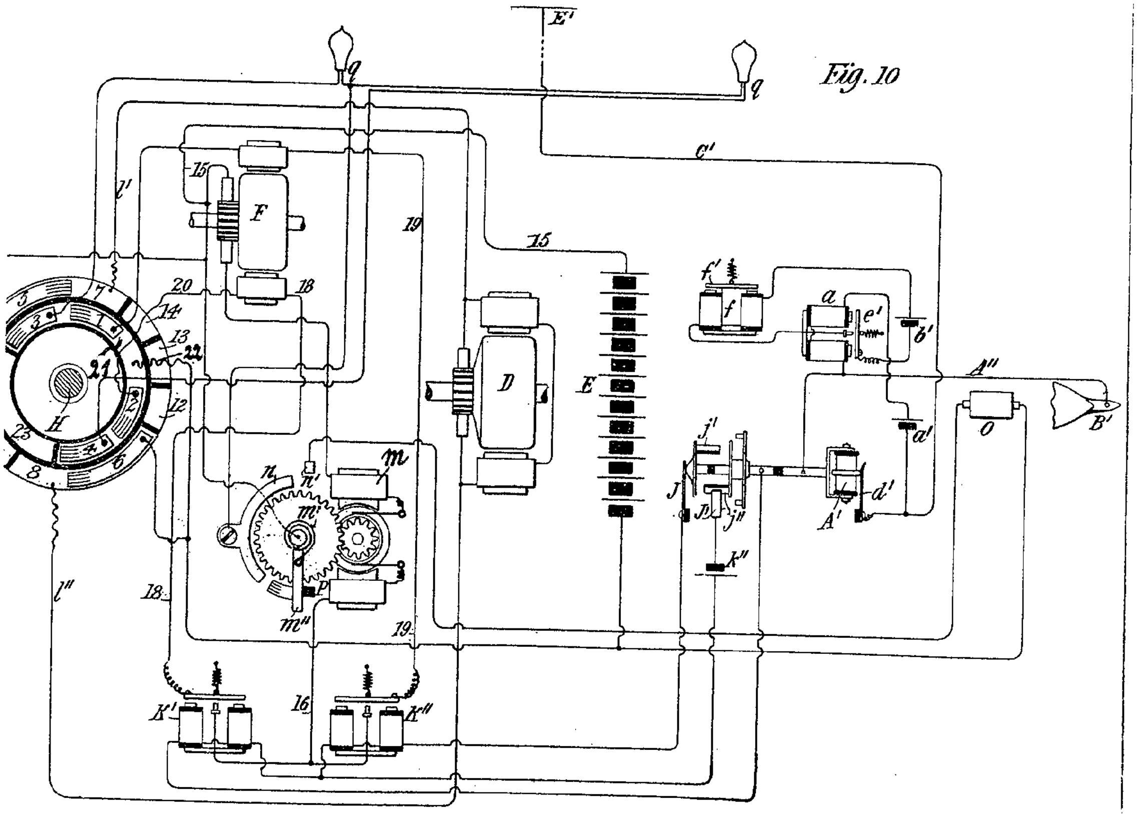


Fig. 10

PHOTOGR. DRUCK DER REICHSDRUCKEREI.

Fig. 5

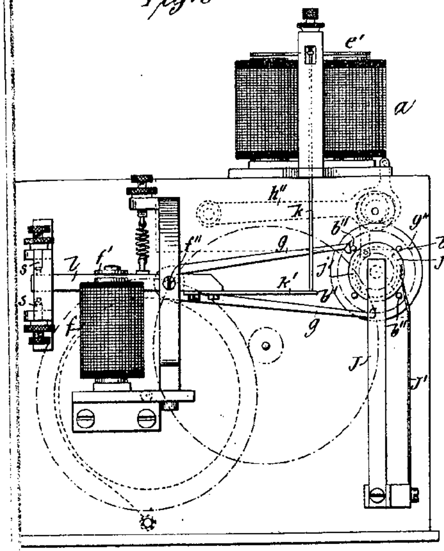


Fig. 6

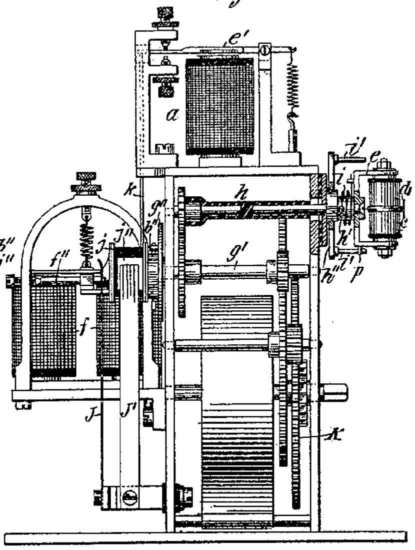


Fig. 4

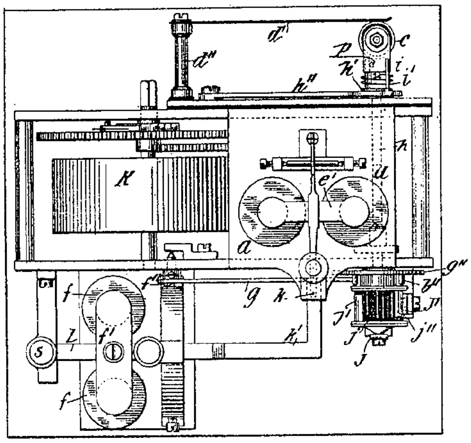


Fig. 8

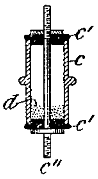
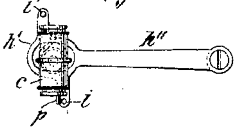


Fig. 7



Zu der Patentschrift

№ 142842.

DANSK PATENT

Nr. 31737.

BESKRIVELSE

MED TILHØRENDE TEGNING,

BEKENDTGJORT DEN 22. MAJ 1923.

Maskin- og Elektroingeniør NIKOLA TESLA,

NEW YORK, FORENEDE STATER I AMERIKA.

Fremgangsmaade og Apparat til Omdannelse af Varmeenergi til mekanisk Energi.

Patent udstedt den 8. Maj 1923, beskyttet fra den 31. Marts 1922. Fortrinsret paaberaabt fra den 1. April 1921, Indleveringsdag for Ansøgning i England.

(Klasse 46: Luft- og Gasmaskiner m. m.)

Til Omdannelse af den i et elastisk Fluidum indeholdte Varmeenergi ved Hjælp af Turbiner anvendes der i Almindelighed to forskellige Fremgangsmaader. Ved den ene strømmer det arbejdende Fluidum gennem stillestaaende Udstrømningsaabninger i fri Straaler, som paavirker Skovlhjul paa Turbinens Rotor, hvorved den opnaaede Hastighedsenergi i Fluidumet omsættes til Omdrejningsenergi ved Aktion. Ved den anden Fremgangsmaade tilføres Fluidumet under sit fulde Tryk til krumme Skovle eller Kanaler i Turbinerotoren, i hvilke det udvider sig, idet det meddeler sin Energi til Rotorskovlene og bevirker, at Rotoren omdrejes ved Reaktion. Af vel kendte tekniske Grunde anvendes der sjældent Turbiner, som arbejder udelukkende efter det ene eller det andet Princip, men begge Fremgangsmaader anvendes i Forening ved moderne Maskiner. Endvidere deles Maskinerne som oftest i forskellige Trin, ved hvilke enten Hastighedstabet eller Tryktabet gennem Maskinen deles i mindre Enheder, hvorved der opnaas en bedre Omformning af Varmeenergien til mekanisk Energi.

Af teoretiske Betragtninger fremgaar det, at en Reaktionsturbine, som er inddelt i Tryktrin, i Almindelighed egner sig bedre til denne Omdannelse af Varmeenergi til mekanisk Energi, idet den har større termodynamisk Virkningsgrad, d. v. s., den omformer en betydelig større Del af Friktionsvarmen end Aktionsturbinen med Hastighedstrin. Paa den anden Side har den førstnævnte Turbine et mere begrænset Temperaturomraade, og som Følge heraf vilde dens Overlegenhed over Aktionsturbinen ikke være saa stor, som Tilfældet er, dersom ikke den relative Hastighed af Fluidumet var betydelig større i Aktionsturbinen, hvilket nedsætter dens Virkningsgrad.

Disse forskellige Fordele og Mangler har ført til Anvendelse af baade Aktions- og Reaktionshjul i den samme Enhed, som derved bliver bedre egnet til Opfyldelse af de Fordringer, der stilles med Hensyn til de anvendte Temperaturer, og som er mere økonomisk arbejdende end de rene Reaktions- eller Aktionsturbiner. Det Temperaturomraade, der kan anvendes, er imidlertid, selv ved en saadan blandet Turbine, ikke særlig stort, og de Fordele, der opnaas ved Anvendelsen af en saadan Turbine er kun ret smaa, i mange Tilfælde endog ganske ubetydelige. Man er i denne Henseende saa at sige naaet til Grænsen for, hvad der kan opnaas ved de eksisterende Turbinetyper, og man er derfor gaaet over til at søge at opnaa Brændselsbesparelse og Besparelser i Installationsomkostninger ad andre Veje og ved Hjælp af andre Midler.

Ved den foreliggende Opfindelse opnaas der et teknisk Fremskridt med Hensyn til større Virkningsgrad ved Omdannelsen af Varmeenergi til mekanisk Energi. Opfindelsen bestaar i en Fremgangsmaade, der gaar ud paa, at en Del af Varmeenergien i det elastiske Fluidum omdannes til mekanisk Energi ved Fluidumets Gnidning mod en passende Maskindel, fortrinsvis ved høj Temperatur, medens Resten af Varmeenergien omsættes til mekanisk Energi ved Aktions- eller Reaktionsvirkning ved en lavere Temperatur.

Det foreliggende Apparat, der egner sig bedst til Udførelse af Fremgangsmaaden, bestaar i en Kombination af en Friktionsturbine, f. Eks. en Turbine som den, der er beskreven i engelsk Patent Nr. 24001/10, og en Reaktionsturbine, f. Eks. en Parson's Turbine. Det arbejdende Fluidum føres til Friktionsturbinen gennem en passende Indstrømningsanordning og gennemløber Mellemrummene mellem Rotorens Skiver, hvorved det udøver et Drejningsmoment paa disse Skiver paa Grund af Gnidningen, saaledes at en Del af den i Fluidumet indeholdte Varmeenergi omsættes til mekanisk Energi. Fra Friktionsturbinens Udstrømningsaabning strømmer Fluidumet derpaa under passende Tryk og Temperatur til en Reaktionsturbine, i hvilken Resten af dets Varmeenergi omsættes til mekanisk Energi ved Reaktionsvirkning.

Det foreliggende Apparat til Udførelse af Fremgangsmaaden er fremstillet paa Tegningen, hvor

Fig. 1 og 2 viser Apparatet i Form af en kombineret Friktions- og Reaktionsturbine, henholdsvis set fra Siden delvis i Snit og set fra oven, og

Fig. 3 et lodret Snit vinkelret paa Aksen gennem Friktionsturbinen.

1 betegner Rotoren i Friktionsturbinen, *2* denne Turbines Hus, der har to Indstrømningskamre *3*, for det arbejdende Fluidum. Indstrømningskamrene har Indstrømningsaabninger *4* og *5*, af hvilke Indstrømningsaabningerne *4* anvendes ved normal Drift af Turbinen, medens Indstrømningsaabningerne *5* anvendes under baglæns Gang af Turbinen. *6* betegner Udstrømningsaabningerne, som fører til et Udstrømningsrør *7*, der atter fører til et Tilførsels- eller Indstrømningsrør *8* for en Indstrømningsventil *9* i Reaktionsturbinen *10*. En Udstrømningsaabning *11* fra Reaktionsturbinen staar i Forbindelse med en Kondensator gennem et Rør *12*, til hvilket der er forbundet et Grenrør *13*, som gennem en Ventil *14* fører til Udstrømningsrøret *7* for Friktionsturbinen. Tilførslen af det arbejdende Fluidum til Friktionsturbinen foregaar gennem og styres af en Ventil *15* i Forbindelse med to andre Ventiler *16* og *17*, der passende kan være indbyrdes mekanisk forbundne, f. Eks. ved en Tandhjulskæde *18*, som bevirker, at de to Ventiler bevæges samtidig, men saaledes, at den ene lukkes, naar den anden aabnes.

Under normal Drift af den kombinerede Turbine er Ventilerne *17* og *14* lukkede, og Fluidumet føres til Friktionsturbinen gennem Ventilerne *15* og *16* og Indstrømningsaabningerne *4*. Efter at have passeret Rotoren *1* strømmer det gennem Udstrømningsaabningerne *6* og Røret *7* til Indstrømningsrøret *8* og Indstrømningsventilen *9* i Reaktionsturbinen *10*, og efter at have passeret denne strømmer det gennem Udstrømningsaabningen *11* og Røret *12* til en Kondensator. Under disse Forhold arbejder saavel Friktions- som Reaktionsturbinen i samme Retning, idet de drejer sig i den Retning, der er angiven ved en med fuldt optrukken Linie vist Pil i Fig. 3. Dersom begge disse Turbiner skal løbe i den modsatte Retning, der er angiven ved en med stiplet Linie optrukken Pil i Fig. 3, lukkes Ventilerne *16* og *9*, medens Ventilerne *17* og *14* aabnes. Herved vil det arbejdende Fluidum træde ind i Friktionsturbinen gennem Indstrømningsaabningerne *5* og efter at have passeret Turbinen forlade denne gennem Aabningerne *6* og strømme til Kondensatoren gennem Rørene *7*, *13* og *12*. Friktionsturbinen vil da dreje sig i den modsatte Retning og trække Reaktionsturbinen med sig. Denne Turbine yder imidlertid kun ringe Modstand paa Grund af det i den herskende Vakuum. Friktionsturbinen udvikler i dette Tilfælde større Energi end i det først beskrevne Tilfælde, da dens Udstrømningsaabninger er umiddelbart forbundne med Kondensatoren, saaledes at Trykfaldet gennem Turbinen er betydelig større end før.

Ved Beregninger, der er understøttede ved Forsøg, har det vist sig, at der kan opnaas betydelige økonomiske Fordele ved denne Fremgangsmaade og i Særdeleshed ved den Turbinekombination, som er beskreven ovenfor.

Denne kombinerede Turbine er særlig anvendelig ved meget høje Temperaturer og Tryk, idet Friktionsturbinen arbejder fordelagtigst ved de høje Temperaturer og Tryk, medens Reaktionsturbinen særlig egner sig for de lavere Temperaturer og ganske lave Tryk. Endvidere tillader Friktionsturbinen, at Fluidumet udvider sig paa passende Maade enten i Indstrømningsaabningerne eller i Rotoren eller begge Steder, og dette bevirker, at man kan indstille Tryk- og Temperaturforholdene saaledes, at begge Turbiner kommer til at arbejde under de gunstigst mulige Betingelser. Den kombinerede Turbine er ganske særlig anvendelig i Tilfælde, hvor der er Brug for Turbineenheder, som skal kunne arbejde med to forskellige Omdrejningsretninger, f. Eks. til Skibsmaskiner, idet den foreliggende Turbinekombination bl. a. langt lettere lader sig omstyre fra Fremad- til Bakgang end de hidtil kendte Skibsturbiner.

Ved de forskellige praktiske Anvendelser af Turbinekombinationen kan man ændre de enkelte Tryk- og Temperaturfald inden for ret vide Grænser, og som et Eksempel kan det anføres, at der er opnaaet udmærket god Virkningsgrad med en Turbinekombination af den ovenfor angivne Art, ved hvilken der anvendes overhedet Damp, som føres til Friktionsturbinen med en Temperatur af omtr. 600° C og strømmer fra denne til Reaktionsturbinen med en Temperatur af omtr. 300° C.

Skønt Friktionsturbinen som Regel vil give de bedste Resultater i Kombination med en Parson's Turbine, egner den sig fortrinligt til at tjene som første Trin i Forbindelse med andre Turbinetyper og kan ogsaa anvendes i Forbindelse med andre Maskintyper, f. Eks. Stempelmaskiner.

Patentkrav.

1. Fremgangsmaade til Omdannelse af Varmeenergi til mekanisk Energi, kendetegnet ved, at en Del af den i et elastisk Fluidum indeholdte Varmeenergi omdannes til mekanisk Energi ved Gnidning, medens en anden Del omdannes til mekanisk Energi ved Aktions- eller Reaktionsvirkning.

2. Fremgangsmaade som den i Krav 1 angivne, kendetegnet ved, at den Del af Varmeenergien, der omdannes ved Gnidning, er i Besiddelse af en høj Temperatur, medens den Del, der omdannes ved Aktions- eller Reaktionsvirkning, har en lavere Temperatur.

3. Apparat til Udførelse af den i Krav 1 angivne Fremgangsmaade, kendetegnet ved Kombinationen af en Friktionsturbine og en Reaktionsturbine.

4. Apparat til Udførelse af den i Krav 1 angivne Fremgangsmaade, kendetegnet ved Kombinationen af en Friktionsturbine med en blandet Aktions- og Reaktionsturbine.

5. Turbinekombination som den i Krav 3 angivne, kendetegnet ved, at Friktions- og Reaktionsturbinerne er koblede umiddelbart til hinanden eller sammenbyggede paa samme Aksel.

6. Turbinekombination som den i Krav 5 angivne, kendetegnet ved, at Friktions- og Reaktionsturbinerne er saaledes forbundne gennem med Ventiler forsynede Rør, at de begge kan arbejde i samme Retning, eller at Reaktionsturbinen kan løbe tom, trukken af Friktionsturbinen.

København 1923. Trykt hos J. H. Schultz A/S.

Henhörer til Beskrivelsen af

Dansk Patent N° 31737

Fig. 1

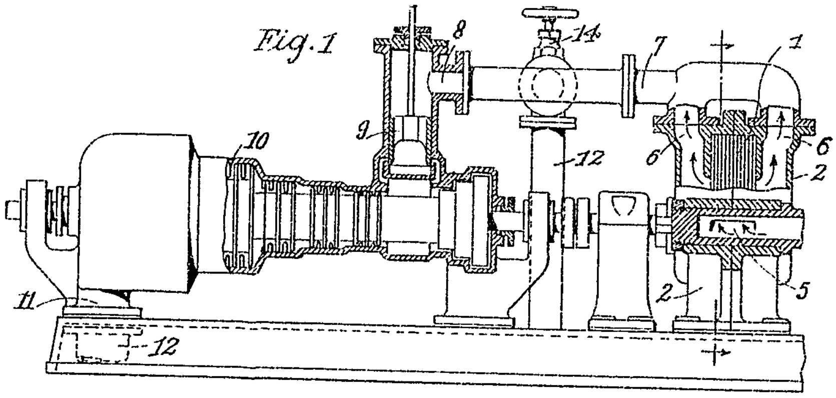


Fig. 3

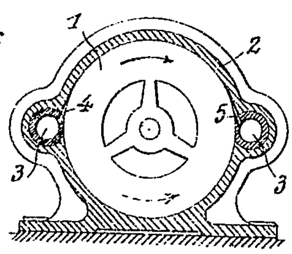
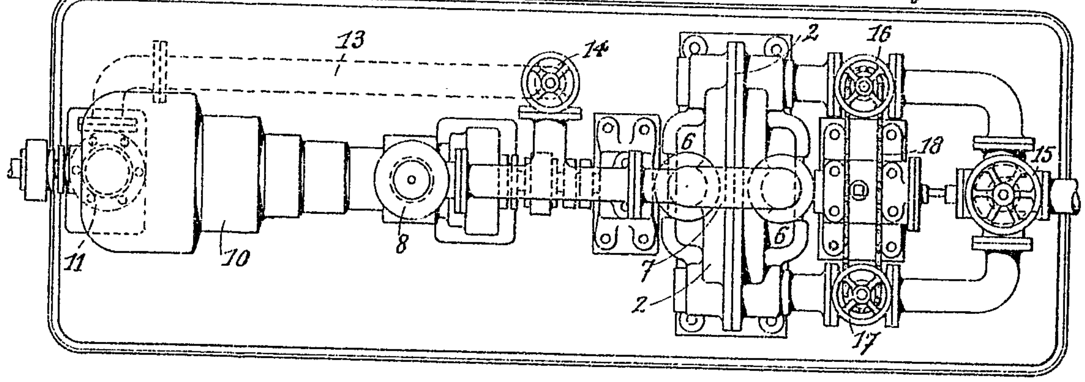


Fig. 2



Fotolitograferet ved Generalstabens topografiske Afdeling 1923

RÉPUBLIQUE FRANÇAISE.

OFFICE NATIONAL DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

XII. — Instruments de précision, électricité.
6. — TRANSPORT ET MESURE DE L'ÉLECTRICITÉ, APPAREILS DIVERS.

N° 354.791

Perfectionnements à la transmission de l'énergie électrique.

M. NIKOLA TESLA résidant aux États-Unis d'Amérique.

Demandé le 18 avril 1905.
Délivré le 8 août 1905. — Publié le 12 octobre 1905.

On sait depuis longtemps, que des courants électriques peuvent être propagés par la terre, et cette connaissance a été utilisée de plusieurs manières dans la transmission des signaux et le fonctionnement d'une variété d'appareils récepteurs éloignés de la source d'énergie, principalement pour se dispenser d'un fil conducteur de retour.

On sait aussi que des perturbations électriques peuvent être transmises par des portions du sol en le reliant à un des pôles de la source seulement, et l'invention a utilisé cette observation dans des systèmes, imaginés dans le but de transmettre par les milieux naturels des signaux intelligibles ou de la force, et qui sont à présent familiers. Mais toutes les expériences et observations faites jusqu'ici ont confirmé l'opinion, partagée par la majorité des savants, que la terre, à cause de son extension immense, quoique possédant des propriétés conductrices ne se comporte pas comme un conducteur de dimensions limitées vis-à-vis des perturbations produites, mais au contraire, plutôt comme un vaste réservoir ou océan qui, quoique pouvant subir une perturbation locale du fait d'une commotion quelconque, reste sans réponse et sans action pour sa plus grande partie ou sa totalité.

Il est encore un autre fait. bien connu maintenant. Lorsque des ondes ou oscillations électriques sont imprimées à un conducteur tel qu'un fil métallique, il y a réflexion sous certaines conditions, des bouts du fil et, par suite de l'interférence des oscillations imprimées et réfléchies, il se produit le phénomène «d'ondes stationnaires», avec des maxima et des minima fixes définies. Dans tous les cas pareils l'existence de ces ondes indique, que quelques-unes des ondes sortantes ont été propagées aux extrémités de la voie conductrice et ont été réfléchies de là.

Or, l'invention est basée sur cette découverte que malgré ces dimensions vastes et à l'encontre de toutes les observations faites jusqu'à ce jour, le globe terrestre peut, en grande partie et même en totalité, se comporter vis-à-vis des perturbations imprimées, comme un conducteur de grandeur limité, ce fait étant démontré par des phénomènes nouveaux, décrits ci-après.

Dans le cours de certaines recherches, ayant pour objet d'étudier les effets des décharges de foudre sur la condition électrique de la terre, l'inventeur a observé que des instruments récepteurs sensibles, arrangés de manière à être capables de répondre à des perturbations électriques occasionnées par les décharges, manquaient quelquefois de répondre et, en examinant ce fait inattendu, il a trouvé qu'il était dû au caractère des ondes électriques qui étaient produites dans la terre par les décharges de foudre et qui avaient des nœuds et des ventres, suivant la source des perturbations qui se déplaçait, à des distances définies. De nombreuses observations des maxima et minima de ces ondes montraient que leurs longueurs variaient, approximativement, de vingt-cinq à soixante-quinze kilomètres; la conclusion tirée de ces résultats et certaines déductions théoriques était que des ondes de ce genre peuvent être propagées dans toutes les directions du globe, et qu'elles peuvent avoir des longueurs encore bien plus différentes, les limites extrêmes étant imposées par les dimensions et propriétés physiques de la terre.

Reconnaissant dans l'existence de ces ondes que les perturbations créées avaient été conduites dès leur origine jusqu'aux portions les plus éloignées du globe et avaient été réfléchies de là, l'inventeur conçut l'idée de produire de telles ondes dans la terre par des moyens artificiels, afin d'en faire usage pour des effets utiles, pour lesquels elles sont, ou pourraient se prouver applicables.

Ce problème était rendu extrêmement difficile à cause des dimensions immenses de la planète et, par suite, du mouvement énorme d'électricité ou activité électrique qu'on devait obtenir pour approcher, même à un degré éloigné, des mouvements et activités évidemment atteints dans les manifestations de force électrique dans la nature, et qui paraissaient d'abord irréalisables par des forces humaines quelconques. Mais par les perfectionnements constants et incessants apportés au générateur d'oscillations électriques, décrit dans les brevets américains n^{os} 645.576 en date du 2 septembre 1897 et 649,621, du 2 septembre 1897, et anglais n° 24.421 du 21 octobre 1897, l'inventeur a réussi finalement à produire des mouvements et des activités électriques, qui non seulement approchent mais, comme de nombreuses mesures comparatives le démontrent actuellement, dépassent ceux des décharges de la foudre; et au moyen de cet appareil il est donc possible de reproduire, à volonté, dans la terre des phénomènes identiques ou semblables à ceux dus à de telles décharges

Grâce à la connaissance de ces phénomènes et des moyens pour accomplir ces résultats, il est possible non seulement d'effectuer beaucoup d'opérations par l'emploi d'instruments connus, mais aussi d'offrir une solution d'un certain nombre de problèmes importants, nécessitant l'opération ou le contrôle d'appareils à distance, et qui, à défaut de cette connaissance et en l'absence de ces moyens, ont été entièrement insolubles jusqu'ici.

Par exemple, au moyen d'un tel générateur d'ondes stationnaires et d'appareils récepteurs, convenablement placés et réglés, dans une autre localité quelconque, n'importe à quelle distance, on peut transmettre des signaux intelligibles; on peut contrôler ou actionner, à volonté, quelques-uns ou tous ces appareils pour beaucoup d'autres résultats d'importance et de valeur, comme pour indiquer, en quel endroit que ce soit, l'heure correcte d'un observatoire; on peut constater la position relative d'un corps ou sa distance par rapport à un point donné; il est possible de déterminer la route d'un objet en mouvement tel qu'un vaisseau sur la mer, la distance traversée par lui ou sa vitesse; de produire à distance beaucoup d'autres effets utiles, qui dépendent ou de l'intensité, ou de la longueur des ondes, ou de la direction ou rapidité de leur mouvement, ou de quelque autre caractère ou propriété de ce genre de perturbations.

Au dessin l'invention est représentée appliquée à l'un de ses emplois spécifiques, à savoir, la transmission des signaux à distance.

La figure 1 représente schématiquement le générateur qui produit des ondes stationnaires dans la terre, la figure 2 est un appareil récepteur dans une localité éloignée et la figure 3 montre l'arrangement des circuits du transformateur récepteur.

A la figure 1, A désigne une bobine primaire formant partie d'un transformateur et consistant généralement en plusieurs tours d'un câble gros de résistance inappréciable, dont les bouts sont reliés aux bornes d'une source d'oscillations puissantes, représentée schématiquement par G. Cette source est usuellement un condensateur chargé à haute tension, et déchargé, en succession rapide, par le primaire, comme dans le transformateur actuellement bien connu, dont la description a été donnée par exemple au brevet français n° 259.940, du 22 septembre 1896. Quand on veut produire des ondes stationnaires de grandes longueurs, un alternateur de construction convenable peut être employé pour donner de l'énergie au primaire A.

C est une bobine secondaire, enroulée en spirale, à l'intérieur du primaire, dont le bout le plus rapproché de ce dernier est relié à la terre E, et l'autre à un point terminal élevé D. Les constantes physiques de la bobine C, déterminant sa période de vibration, sont choisies et disposées de manière que le système secondaire E C D soit en résonnance la plus parfaite possible avec les oscillations imprimées sur elle par le primaire A. Il est, en outre, de la plus grande importance, pour élever encore plus la tension et augmenter le mouvement électrique dans le système secondaire, que sa résistance soit aussi petite que possible et sa self-induction aussi grande que possible sous les conditions imposées. La connexion à la terre doit être faite avec le plus grand soin pour en réduire la résistance.

Au lieu d'être directement reliée à la terre, comme il est indiqué, la bobine C peut être reliée, en série ou autrement, au primaire A, dans lequel cas ce dernier sera relié à la plaque E. Mais qu'aucun, ou une partie, ou tous les tours primaires excitateurs soient inclus dans la bobine C, la longueur totale du conducteur depuis la plaque E dans la terre jusqu'au terminal élevé D doit être égale à un quart de la longueur des ondes de la perturbation électrique dans le système E C D, ou bien égale à cette longueur multipliée par un nombre impair. Cette relation étant observée, le terminal D coïncidera avec les points de tension maximum dans le circuit secondaire ou excité, et le plus grand flux d'électricité y aura lieu. Pour augmenter autant que possible le mouvement électrique dans le secondaire, il est essentiel que sa connexion inductive avec le primaire A ne soit pas trop intime, comme dans les transformateurs ordinaires, mais faible, afin de permettre une oscillation libre. C'est-à-dire que leur induction mutuelle doit être petite. La forme spirale de la bobine C offre cet avantage et en même temps les tours près du primaire A sont soumis à une action inductive forte et développent une haute force électromotrice initiale.

Ces dispositions étant soigneusement exécutées et les autres caractères constructifs indiqués rigoureusement observés, le mouvement électrique produit dans le système secondaire par l'action du primaire A sera énormément renforcé, l'augmentation étant directement proportionnelle à l'inductance et à la fréquence, et en raison inverse de la résistance du système secondaire. Il est ainsi possible de produire de cette manière un mouvement électrique des milliers de fois plus grand que l'initial; c'est ainsi qu'on a pu atteindre des activités électriques dans le système E C D, mesurées par des milliers de chevaux-vapeur. De tels mouvements immenses d'électricité donnent naissance à des phénomènes nouveaux et frappants, parmi lesquels ceux ci-dessus décrits. Les puissantes oscillations électriques dans le système E C D, étant communiquées à la terre, causent des vibrations correspondantes capables d'être propagées jusqu'aux régions les plus éloignées du globe, d'où elles sont réfléchies, et, par interférences avec les vibrations sortantes, produisent des ondes stationnaires, dont les nœuds et ventres sont situés dans des cercles parallèles, relativement auxquels la plaque E peut être considérée comme pôle. Autrement dit, le conducteur terrestre est mis en résonnance avec les oscillations imprimées, exactement comme un fil. Bien plus, un certain nombre de faits ainsi déterminés montrent clairement, que le mouvement d'électricité par la terre suit certaines loi avec une rigueur presque mathématique. Pour le moment il est suffisant de dire que la planète se comporte comme un conducteur parfaitement lisse et poli, d'une résistance inappréciable, avec la capacité et self-induction distribuées uniformément par rapport à l'axe de symétrie de la propagation des ondes, et transmettant des oscillations électriques lentes sans distorsion ni atténuation sensibles. En outre de cela, trois exigences semblent être essentielles pour l'établissement de la condition résonnante :

1° Le diamètre de la terre passant par le pôle E doit être un multiple impair du quart de la longueur d'onde, c'est-à-dire du rapport entre la vitesse de la lumière et quatre fois la fréquence du courant.

2° Il est nécessaire d'employer des oscillations dans lesquelles la proportion de radiation d'énergie dans l'espace sous forme d'ondes hertziennes et électromagnétiques est très petite. Pour en donner une idée, la fréquence doit être moins de vingt mille par seconde, bien que des ondes plus courtes pourraient être utilisées. La plus basse fréquence paraît être six par seconde, dans lequel cas il n'y aura qu'un nœud, situé à la plaque de sol ou pôle E et, quoique cela puisse sembler paradoxal, l'effet augmentera avec la distance et sera maximum dans une région diamétralement opposée au transmetteur. Avec des oscillations encore plus lentes la terre, strictement, ne sera pas mise en résonnance, mais fonctionnera simplement comme une capacité, et les variations du potentiel seront plus ou moins uniformes sur toute sa surface.

3° L'exigence la plus essentielle est, pourtant, que, quelle que soit la fréquence employée, l'onde ou le train d'ondes doit continuer pendant un certain intervalle de temps, lequel ne doit pas être moins d'un douzième de seconde — ou probablement de 0.08484 d'une seconde — qui est utilisé, à l'aller et retour à la région diamétralement opposée du pôle, par-dessus la surface de la terre, avec une vitesse moyenne d'environ 471,240 kilomètres par seconde.

La présence des ondes stationnaires peut être constatée de beaucoup de manières. Par exemple, un circuit peut être relié directement, ou inductivement, à la terre, et à un terminal élevé, et syntonisé pour répondre plus effectivement aux oscillations. Une autre manière est de relier un circuit syntonisé à la terre à deux points situés plus ou moins dans un méridien passant par le pôle E, ou, en général, à deux points quelconques de potentiel différent.

Sur la figure 2 est montré un dispositif pour découvrir la présence des ondes, tel qu'il est employé dans une nouvelle méthode pour augmenter des effets faibles, et qu'il est décrit dans les patentes américaines 685.953 du 24 juin 1899 et 685.955 du 24 juin 1899. Il consiste en un cylindre C^2 en matière isolante, qui est tourné à vitesse uniforme, par un mouvement d'horlogerie ou autre force motrice convenable, et qui est muni de deux anneaux métalliques B et B^1, sur lesquels portent deux balais a et a^1, reliés, respectivement, aux plaques des terminaux P et P^1. Depuis les anneaux B et B^1 s'étendent des segments métalliques étroits S et S^1, qui par la rotation du cylindre C^2, sont mis alternativement en contact avec les balais doubles b et b^1, supportés par les porte-balais conducteurs h et h^1 avec lesquels ils sont en contact, ces porte-balais étant maintenus dans des collets métalliques D^2 et D^3, comme il est montré. Ces derniers sont reliés aux terminaux T et T^1 d'un condensateur C^3, et ils sont capables de déplacement angulaire comme des porte-balais ordinaires. L'emploi de deux balais, comme b et b^1, dans chacun des porte-balais h et h^1 permet de varier à volonté la durée du contact électrique entre les plaques P et P^1, et les terminaux T et T^1, auxquels est relié un circuit contenant un récepteur R, et un dispositif qui ferme le circuit à des intervalles de temps prédéterminés et décharge l'énergie accumulée par le récepteur. Dans le cas présent ce dispositif consiste en un cylindre d, composé en partie de matière conductrice et de matière isolante e et e^1, respectivement, qui est tourné à la vitesse désirée par des moyens convenables quelconques. La partie conductrice e est connectée électriquement avec l'arbre S^2, et est munie de segments coniques fff, sur lesquels glisse un balai k, supporté par une tige conductrice l, capable d'être réglée longitudinalement dans un support métallique m. Un autre balai n est arrangé de manière à porter sur l'arbre S^2, de telle façon que toutes les fois qu'un des segments f vient en contact avec le balai k, ce circuit contenant le récepteur R est complété et reçoit la décharge du condensateur. En réglant la vitesse du cylindre d et en déplaçant le balai k le long du cylindre, le circuit peut être interrompu et fermé dans une succession aussi rapide qu'on le désire, et rester ouvert ou fermé pendant de tels intervalles de temps.

Les plaques P et P^1, au moyen desquelles l'énergie électrique est communiquée aux balais a et a^1, peuvent être à une distance considérable l'une de l'autre dans le sol, ou l'une dans le sol et l'autre dans l'air, de préférence à une élévation considérable. Si une plaque seulement est reliée à la terre et l'autre maintenue à une certaine hauteur, l'emplacement de l'appareil sera déterminé par rapport à la position des ondes stationnaires, l'effet étant évidemment le plus grand dans une région ventrale, et zéro dans une région nodale. D'autre part, si les deux plaques sont reliées à la terre, les deux points de connexion doivent être choisis eu égard aux différences de potentiel produites, l'effet le plus fort étant naturellement obtenu quand les plaques sont à une distance égale à la moitié de la longueur d'onde.

Pour donner un exemple du fonctionnement du système, on peut supposer que des impulsions électriques alternatives du générateur produisent des ondes stationnaires dans la terre, comme il a été décrit ci-dessus, et qu'un appareil récepteur a été convenablement placé par rapport à la position des régions nodales et ventrales des ondes. La vitesse de rotation du cylindre C^2 est modifiée jusqu'à ce qu'il tourne synchroniquement avec les impulsions alternatives du générateur, et les balais *b* et b^1 sont réglés, par déplacement angulaire, ou autrement, de manière à être en contact avec les segments S et S^1, pendant les périodes où les impulsions sont au maximum de leur intensité ou en approchent. Des charges électriques de même signe seront alors communiquées à chacune des bornes du condensateur, et à chaque impulsion nouvelle celui-ci sera chargé à un potentiel plus élevé. La vitesse de rotation du cylindre *d* étant réglable à volonté, l'énergie d'un nombre quelconque d'impulsions séparées peut être accumulée de cette manière sous forme potentielle, et déchargée par le récepteur R, lorsque le balai *k* fait contact avec un des segments *f*. On comprendra que la capacité du condensateur doit pouvoir permettre l'accumulation d'une quantité d'énergie beaucoup plus grande que celle nécessaire pour l'opération ordinaire du récepteur. Puisque par cette méthode une quantité d'énergie relativement grande, et sous forme convenable, peut être rendue disponible pour l'opération d'un récepteur, il n'est pas nécessaire que celui-ci soit très sensible. Mais lorsque les impulsions sont très faibles, et quand on veut actionner un récepteur très rapidement, n'importe lesquels des dispositifs sensibles bien connus, capables de répondre à des influences faibles, peuvent être employés de la manière indiquée, ou autrement.

Sous les conditions décrites il est évident que, pendant l'existence des ondes stationnaires, le récepteur sera actionné par les impulsions de courant plus ou moins intenses, suivant sa localisation par rapport au maxima et mimima desdites ondes. En interrompant ou réduisant le flux du courant, les ondes stationnaires disparaîtront ou diminueront d'intensité. De là s'ensuit une grande variété d'effets produits dans un récepteur suivant la façon dont les ondes sont réglées. Il est possible, d'ailleurs, de placer les régions nodales et ventrales des ondes à volonté depuis la station transmettrice, par exemple, en variant la longueur des ondes tout en observant les exigences indiquées ci-dessus. De cette manière les régions d'effet maximum et minimum peuvent être amenées à coïncider avec une station particulière ou des stations réceptrices quelconques. En imprimant à la terre deux ou plusieurs oscillations de longueurs différentes, on peut produire une onde «stationnaire», résultante traversant le globe avec une vitesse voulue, et ainsi obtenir une grande variété d'effets utiles. La route d'un vaisseau sera évidemment déterminée facilement sans l'emploi d'un compas, en reliant un circuit à la terre à deux points, l'effet exercé sur le circuit étant maximum lorsque les plaques P P^1 sont situées sur un méridien passant par la plaque E, et nul quand les plaques se trouvent sur un cercle parallèle. Si les régions nodales et ventrales sont maintenues dans des positions fixes, la vitesse d'un vaisseau portant un appareil récepteur peut être exactement calculée, en observant les régions maxima et minima successivement traversées. Pour la compréhension de ce fait, il faut dire que les projections de toutes les parties nodales et ventrales sur le diamètre de la terre passant par le pôle E, c'est-à-dire sur l'axe de symétrie du mouvement des ondes, sont toutes égales. Donc dans chaque région terrestre la longueur d'onde peut être déterminée par des simples règles de géométrie. Réciproquement, connaissant la longueur d'onde, la distance de la source peut être facilement calculée. Pareillement, la distance d'un point à un autre, la latitude et longitude, l'heure, etc., peuvent être facilement déterminées par l'observation de telles ondes. Si plusieurs générateurs d'ondes stationnaires — de préférence de longueurs différentes — étaient installés dans des localités judicieusement choisies, le globe entier pourrait être subdivisé en des zones d'activité électrique définies, et ces résultats et beaucoup d'autres de même importance pourraient être obtenus immédiatement par de simples calculs ou par les indications des instruments proprement gradués.

Le plan spécifique ici décrit pour produire les ondes stationnaires est capable de modifications. Par exemple, le circuit qui imprime les puissantes oscillations sur la terre pourrait lui être relié en deux points.

En tirant de l'énergie de ces ondes à une distance de leur source située dans n'importe quelle région terrestre et pour quelque travail que ce soit, spécialement en quantité considérable, on obtiendra les meilleurs résultats économiques par l'emploi du transformateur récepteur synchronisé. Cette invention forme partie du système de transmission d'énergie par les milieux naturels, décrit en détail dans les brevets précités, mais pour la clarté de cette description l'arrangement des circuits est diagrammatiquement illustré à la figure 3. La partie essentielle du transformateur est un circuit $E^1 C^1 D^1$ qui est connecté, arrangé et réglé de la même manière que le circuit transmetteur E C D et qui est fermé inductivement sur un circuit secondaire A^1. Ce dernier sera naturellement enroulé avec autant de tours qu'on aura besoin pour le meilleur fonctionnement de l'appareil désigné par M. Le transformateur récepteur est bien syntonisé avec les oscillations du transmetteur, de façon que, indépendamment de la longueur du conducteur $E^1 C^1 D^1$, les points de potentiel maximum coïncideront avec le terminal élevé D^1. Dans ces conditions la quantité de l'énergie dérivée des ondes sera la plus grande.

Quand on veut actionner indépendamment un grand nombre d'appareils par des ondes stationnaires de longueurs différentes, on peut se servir des principes décrits dans le brevet français n° 313.188 du 2 août 1901, pour rendre non interférants et non interférables les signaux ou quantités d'énergie destinées à chaque appareil récepteur.

RÉSUMÉ.

Les principaux points caractéristiques de l'invention sont les suivants :

1° L'établissement d'ondes stationnaires dans le globe terrestre.

2° Les moyens de production de ces ondes.

3° La mise en marche, par ces ondes, d'appareils récepteurs situés à des distances quelconques.

4° La variation des longueurs des ondes.

5° Le déplacement des régions nodales et ventrales.

6° La production d'ondes résultantes se déplaçant à une vitesse quelconque par la combinaison de plusieurs ondes stationnaires de longueurs différentes.

7° La variation de l'intensité des ondes ou de leurs autres éléments physiques pour l'actionnement d'appareils récepteurs.

8° La combinaison d'ondes issues de pôles différents.

9° L'emploi d'oscillations électriques durant environ un sixème de seconde et donnant lieu à une seule onde stationnaire.

10° Le procédé consistant à mettre le globe terrestre en résonnance au moyen d'ondes électriques de longueur et de durée déterminées.

11° L'appareil transmetteur.

12° L'appareil générateur destiné à produire l'état de résonnance.

13° Le transformateur agencé pour produire des mouvements considérables d'électricité dans le globe terrestre.

14° L'appareil générateur d'oscillations électriques primaires en combinaison avec un circuit secondaire disposé pour mettre le globe en résonnance.

N. TESLA.

Par procuration :

E. Blétry.

Imprimerie nationale. — Pour la vente, s'adresser à la Société BELIN et Cie, 56, rue des Francs-Bourgeois. Paris (3e).

N° 354.791 M. Tesla Pl. unique

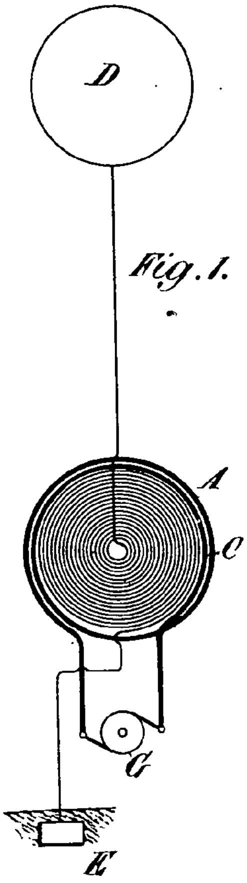
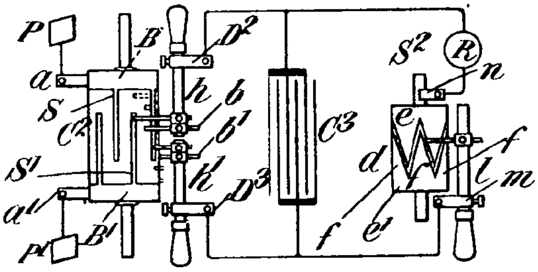


Fig. 1.

Fig. 2.



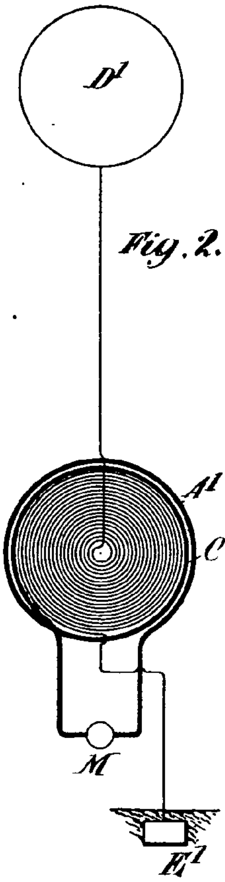


Fig. 2.

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BREVET D'INVENTION.

XII. — Instruments de précision, électricité.

3. — Poids et mesures, instruments de mathématiques, compteurs et procédés d'essai.

N° 541.113

Procédé et appareil pour équilibrer les pièces tournantes des machines.

M. Nikola TESLA résidant aux États-Unis d'Amérique.

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Dans le fonctionnement des machines, l'équilibrage soigné des organes tournants est d'une grande importance économique, car des sommes considérables d'argent sont annuellement dépensées par suite des défectuosités dues au manque d'équilibrage, d'où résultent des pertes de force, une usure anormale, des interruptions dans le service et des accidents plus ou moins graves.

Avant le développement des machines modernes à grande vitesse, l'équilibrage statique était entièrement employé et encore maintenant c'est fréquemment le cas. La tendance croissante dans le sens des grandes vitesses a nécessité un équilibrage dynamique et on a proposé divers genres d'appareils pour atteindre ce but.

Le procédé faisant l'objet de l'invention permet d'atteindre ce but rapidement et avec un haut degré de précision. En résumé il consiste à faire tourner à une vitesse convenable la pièce à équilibrer supportée élastiquement et à enlever l'excès de matière du côté le plus lourd par rodage jusqu'à obtention du degré désiré de perfection d'équilibrage.

Comme moyens d'exécution de l'invention on emploie une meule, des jets de sable ou d'autres substances de rodage. On doit évidemment objecter que le contact d'une meule à émeri ou en carborundum avec la partie d'une machine tournant rapidement est susceptible de produire des chocs et des vibrations dangereuses et également que le rodage à des vitesses beaucoup plus élevées que cela ne se pratique ordinairement ne peut pas donner satisfaction. Mais bien que ces considérations théoriques paraissent fondées, on n'a toutefois pas trouvé de difficultés dans leur application suivant les données de l'invention et il en a été fait usage avec la plus grande facilité et le plus grand succès. On l'attribue à l'inertie du corps tournant qui le rend insensible aux perturbations asynchrones que la meule peut produire. Néanmoins dans certains cas il peut être plus avantageux ou préférable d'effectuer l'enlèvement de l'excès de matière par un jet très rapide de substances rodantes, jet qui est dirigé tangentiellement sur la surface à équilibrer. Pour obtenir les meilleurs résultats, il est essentiel que la pièce à équilibrer mise en rotation puisse subir un déplacement appréciable de son centre de gravité par rapport à son axe de symétrie. Ceci est obtenu en montant cette pièce sur un arbre de flexibilité convenable ou porté dans les paliers élastiques, si toutefois l'arbre sur lequel est monté la pièce à équilibrer n'est pas lui-même suffisamment élastique. Il est en outre de grande importance pour éviter les vibrations nuisibles à la bonne application du procédé que la vitesse à laquelle le rodage est effectué soit en rapport avec la vitesse critique correspondante à la vibration naturelle fondamentale. On observera la règle suivante : si le système repose sur deux paliers la vitesse de rodage sera un multiple ou sous-multiple impair de la vitesse critique. Si d'autre part, l'arbre portant la pièce à roder est supporté d'un seul côté, la vitesse sera un multiple ou sous-multiple pair de la vitesse critique.

Lorsque la pièce à équilibrer a pris la vitesse convenable, on amène la meule de rodage en contact avec la périphérie ou tout autre partie de la pièce à roder. En cours d'action, la flexion de l'arbre diminue jusqu'à ce que finalement le centre de symétrie du système coïncide avec son centre de gravité ou sensiblement. Un opérateur compétent peut s'en rendre compte de différentes manières sans l'emploi de moyens spéciaux, mais on peut utiliser dans ce but des appareils dont les indications sont perçues par les yeux ou l'oreille.

Avant l'application du procédé il est bon de faire tourner la pièce à équilibrer à une vitesse très faible et de la vérifier avec la meule. S'il existe une flexion appréciable de l'arbre lorsque le système repose horizontalement, le rodage peut être fait dans la position verticale qu'il occupe en équilibre statique. Une pièce qui doit être employée avec un arbre rigide, peut être montée sur un autre arbre suffisamment flexible, et comme il existe des limites dans la précision d'ajustage d'un manchon cylindrique, on peut employer un manchon conique pour assurer une plus grande précision. Toutefois on peut obtenir des résultats satisfaisants en munissant l'arbre rigide de prolongements flexibles ou bien en le montant dans des paliers avec supports élastiques. Dans tous les cas, il est désirable de graisser avec un lubrifiant d'une viscosité considérable. Lorsque les pièces à équilibrer doivent tourner dans un milieu à haute température on peut les renfermer dans une enveloppe où on maintient une température équivalente et on ménage une ouverture pour le passage de la meule ou du jet qui doit faire le rodage.

L'invention sera clairement comprise en se référant aux dessins annexés montrant un moyen d'exécution de l'appareil que l'on a trouvé pour l'équilibrage rapide et convenable des pièces de machines par exemple des rotors des turbines à vapeur et à gaz du système Tesla. La fig. 1 montre le dispositif général du système qui comprend une boîte-enveloppe avec une ouverture sur un côté, un moteur pour faire tourner la meule, un tachymètre permettant de se rendre compte à chaque moment de la vitesse, un appareil pour permettre de voir continuellement le degré de précision obtenu et un appareil réchauffeur pour avoir la température désirée.

La fig. 2 est une coupe à travers la boîte dans le plan du disque rotor montrant l'ouverture et également la tuyère de la turbine.

La fig. 3 est une vue des parties essentielles de l'instrument indicateur d'équilibrage.

La fig. 4 montre la manière d'appliquer le jet de rodage suivant les données de l'invention.

En se référant d'abord particulièrement à la première figure, 1 indique la boîte renfermant le rotor à équilibrer qui est mis en rotation par de l'air comprimé ou de la vapeur et cette boîte porte une ouverture 2 pour permettre le passage de la meule 3 qui est en contact avec les surfaces à roder. On peut employer tout moteur convenable pour actionner la meule mais de préférence on emploie un moteur électrique en montant directement la meule sur l'arbre d'un moteur 4 monté sur un chariot 5 qui glisse sur les rails 6, 6 et ce moteur comporte les moyens convenables 7 et 8 pour le déplacer dans le sens de son axe et perpendiculairement à cet axe.

Comme montré sur la fig. 2 la boîte-enveloppe se compose de deux parties 9 et 10 réunies dans leur plan médian horizontal au moyen de surfaces dressées avec soin pour bien assurer leur assemblage et leur déplacement latéral est empêché au moyen de goujons 11, 11 encastrés dans les parties 9 ou 10 de l'enveloppe. D'un côté, les deux parties de la boîte sont prolongées de façon à constituer une cavité cylindrique dans laquelle est ajusté avec soin un cylindre creux 13 comportant une tuyère 14 et un orifice d'admission 15 directement connecté avec le tuyau d'alimentation 16 muni d'une valve de commande. L'ouverture 2 pour donner passage à la meule 3 est indiquée comme étant en communication avec l'extérieur, mais dans certains cas on introduit la meule par un élargissement semblable situé du côté droit ce qui est souvent avantageux lorsqu'on équilibre un rotor dans sa propre enveloppe.

En se référant de nouveau à la fig. 1 les paliers 17 et 18 sont aussi divisés horizontalement dans le plan de jonction des deux parties 9 et 10 de la boîte et ils peuvent faire corps avec ces parties pour éviter une perte de temps et de travail. Les parties inférieures des paliers sont munies de tuyaux 19 et 20 d'adduction et d'écoulement de lubréfiant. Le tuyau d'alimentation 16 est indiqué comme étant connecté à un serpentin 21 d'un réchauffeur 22 muni d'une valve pour contrôler l'écoulement du fluide réchauffant et ce réchauffeur peut avoir toutes formes appropriées. Une vis avec roue hélicoïdale 23 est montée à l'extrémité de l'arbre du rotor pour actionner le tachymètre 24 au moyen d'une connection flexible, ce système peut être quelconque mais on a trouvé avantageux d'employer un type à friction à air. Sur l'autre extrémité de l'arbre est monté l'indicateur d'équilibrage 25, montré en détail fig. 3. Cet indicateur est constitué par une pièce 26 avec aiguille 27 dans le haut et un poids réglable 28 dans le bas. Cet indicateur est monté sur le chemin de roulement extérieur 29 d'un palier à billes 30, dont le chemin de roulement intérieur est fixé à l'arbre et suit ses oscillations, le dégré d'oscillation de l'aiguille étant déterminé par la position du contrepoids. Une échelle graduée 32 est fixée à la partie fixe de l'instrument qui est placé pour être facilement observé par l'opérateur.

Le même appareil peut être employé en supprimant toutefois la meule 3, avec le dispositif indiqué schématiquement sur la fig. 4. Une tuyère 32 projette un jet 33 de matière rodante tangentiellement sur la pièce 34 à équilibrer et qui est montée sur un arbre flexible 35. Dans ce cas la tuyère est montée sur un chariot 5 pour pouvoir la régler dans deux directions.

L'équilibrage se fait comme suit : le rotor étant en position pour le rodage, la boîte enveloppe 9 et les chapeaux des paliers 17 et 18 sont mis en place, le lubrifiant est envoyé sous pression par les tuyaux 19 et 20 et le fluide moteur ou air comprimé est admis par la tuyère 14, sa quantité et sa température étant réglées respectivement par les valves du tuyau d'alimentation 16 et du réchauffeur 22. Le fluide en traversant le rotor et en s'échappant par le bas de la boîte lui imprime un mouvement de rotation et l'amène à la vitesse désirée contrôlée par la lecture faite sur le tachymètre 24. La meule de rodage 3 est maintenant mise en contact avec le rotor et on note sur l'échelle graduée l'indication de l'instrument d'équilibrage. Au départ l'oscillation de l'aiguille est généralement considérable en raison de ce que une vibration de l'arbre, même légère, augmente grandement la pression sur les billes et en conséquence la torsion sur l'instrument. En même temps que l'équilibrage s'améliore, l'effort de torsion diminue jusqu'à ce que finalement l'aiguille atteint le zéro de l'échelle indiquant qu'on a obtenu le degré désiré de perfection d'équilibrage. Comme vérification l'opérateur peut alors faire tourner le moteur à environ la vitesse critique. Cela ne donnera lieu à aucune vibration appréciable et n'influencera par l'indicateur d'équilibrage qui au lieu de porter un poids peut être muni d'un ressort pour produire la pression désirée sur l'anneau de billes et faire opposition à la torsion.

Lorsque on a à équilibrer des pièces que l'on ne peut pas mettre en rotation de la manière indiquée, le mouvement de rotation leur sera communiqué indépendamment par courroies, électricité ou de toute autre manière en prenant soin que l'appareil ne soit pas troublé par d'autres vibrations qui lui seraient communiquées. Afin de conserver intact le contour périphérique si cela est essentiel, on rode le corps à un autre endroit et quand c'est désirable, dans ce but on dispose spécialement pour cela le modèle et la construction de la pièce.

On a trouvé que le procédé était d'une grande valeur pour l'équilibrage des rotors à grande vitesse des turbines à gaz et à vapeur, mais il a été employé avec succès dans une grande variété de cas et l'invention n'est pas limitée à un genre quelconque d'appareils.

RÉSUMÉ.

L'invention a pour objet un procédé pour l'équilibrage des pièces tournantes des machines et un appareil pour la mise en application.

Elle présente les particularités suivantes considérées séparément ou en combinaison :

1° Le procédé pour équilibrer une pièce qui consiste à la faire tourner sur des supports élastiques et à enlever la matière en excès par rodage jusqu'à ce que l'équilibrage soit obtenu.

2° L'équilibrage de la pièce en la montant sur un arbre flexible et en la faisant tourner dans les conditions normales où elle doit travailler.

3° L'équilibrage de la pièce en la faisant tourner sur un arbre flexible convenable porté sur deux paliers, à une vitesse qui est un multiple ou sous-multiple impair de la vitesse critique et en enlevant par rodage la matière en excès.

4° L'équilibrage de la pièce en la montant sur un arbre flexible supporté seulement d'un côté et en la faisant tourner à une vitesse multiple ou sous-multiple pair de la vitesse critique et en enlevant par rodage la matière en excès.

5° L'instrument pour indiquer l'intensité de vibration comprenant un palier à billes ayant un de ses chemins de roulement fixé à l'arbre tournant et portant sur l'autre chemin de roulement une aiguille avec contre-poids.

Nikola TESLA.

Par procuration :

Louis Tailfer.

Fig. 4

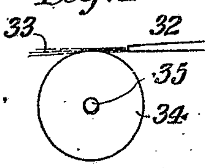
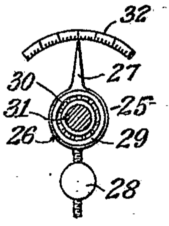


Fig. 3



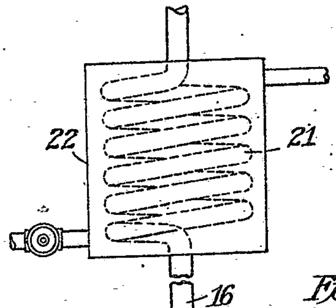


Fig. 1

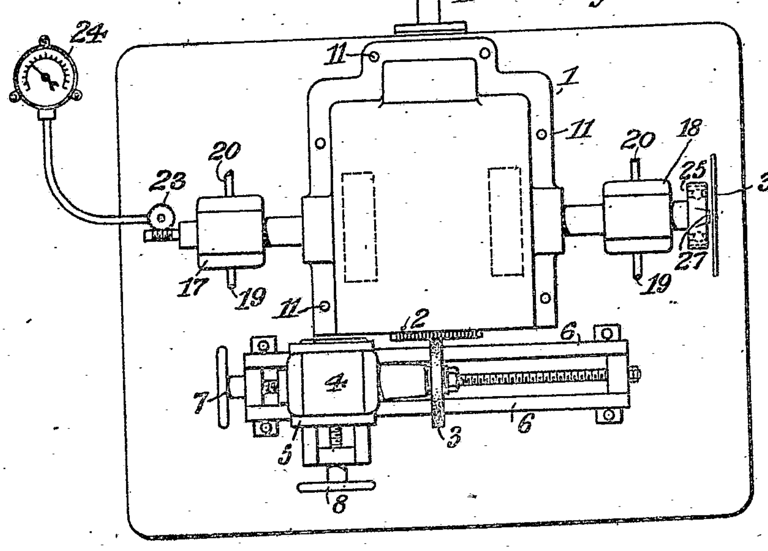
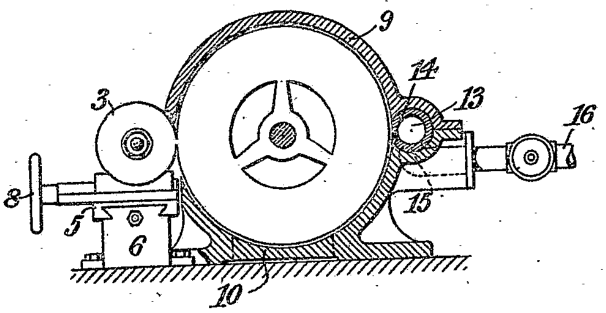


Fig. 2



RÉPUBLIQUE FRANÇAISE.

OFFICE NATIONAL DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

V. — Machines.
8. — Moteurs divers.

N° 549.259

Procédé et appareils pour la transformation économique de l'énergie de la vapeur au moyen de turbines.

M. Nikola TESLA résidant aux États-Unis d'Amérique.

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Le principal objet des perfectionnements de l'invention est d'augmenter l'efficacité de la vapeur dans les machines existantes et des transformations thermodynamiques qui y sont opérées, mais ces perfectionnements peuvent encore trouver leur application en dehors des installations existantes et leur but en général est d'obtenir plus économiquement une puissance motrice au moyen de la vapeur mélangée avec des produits de la combustion et en même temps la machine est susceptible d'être actionnée par la vapeur seule. Nonobstant la multiplication des machines hydro-électriques et à gaz, la plus grande partie de la force motrice est encore obtenue à l'aide de la vapeur, mais le rendement du combustible est relativement très faible à cause des limites imposées par le procédé thermique lui-même, tel qu'il est mis actuellement en œuvre et par certaines insuffisances des formes actuelles d'appareils. Ces inconvénients ont été largement supprimés par le procédé de l'invention qui est très économique, facilement applicable aux machines actuellement en fonctionnement sans nécessiter d'importantes modifications et il devient particulièrement avantageux si l'on se sert de la turbine ou machine rotative décrite dans le brevet français Tesla n° 421.543 du 17 octobre 1910 et des perfectionnements qui ont été apportés depuis à cette turbine. Cette machine peut fonctionner d'une façon satisfaisante à des températures plus hautes que cela n'était possible jusqu'à présent avec un combustible bon marché, contenant un pourcentage élevé d'impuretés et sans que son efficacité en soit matériellement affectée pour causes dues à l'oxydation, à la rugosité des surfaces métalliques, ou autres détériorations du même genre qui nuisent sérieusement au fonctionnement des autres machines thermiques.

Dans l'application de l'invention aux machines à vapeur, on emploie de l'air sous une pression à peu près égale à celle du bouilleur pour brûler le gaz, de l'huile crue, du combustible colloïdal ou du charbon en poudre dans une chambre ou conduit et les produits de la combustion s'échappent mélangés avec de la vapeur dans leur parcours pour se rendre à la turbine avec dilution et refroidissement à la température désirée.

Les dispositions pour atteindre ce but peuvent beaucoup varier suivant les conditions particulières. Dans les stations centrales, factoreries, à bord des bateaux et dans divers autres lieux, l'air comprimé aussi bien que la vapeur sont faciles à se procurer, il est facile d'emmagasiner du combustible et de l'avoir sous la main.

En ce cas les perfectionnements de l'invention pourront être facilement appliqués au moyen de peu d'appareils supplémentaires et à peu de frais. Si les circonstances le demandent, on installe un compresseur d'air et parfois aussi un compresseur de gaz actionné soit directement par l'arbre du moteur primaire ou indépendamment par l'électricité, la vapeur ou toute autre force motrice. Généralement ces machines seront du type le plus efficace à mouvement alternatif, mais on peut employer des compresseurs rotatifs ou de types combinés pour assurer divers avantages. Indépendamment des arrangements particuliers, la combustion et le mélange sont effectués lorsque les fluides ont un mouvement rapide dans une conduite extrêment rapprochée de la turbine et ainsi on évite la plupart des difficultés précédemment rencontrées, et on réduit la radiation et autres causes de pertes qui auraient lieu dans le passage à travers de longs tuyaux. Pour mieux assurer les conditions d'un travail normal, on peut ajouter à l'équipement un système de construction en usage pour égaliser les pressions de vapeur et d'air. La quantité de vapeur est réglée de telle façon que le mélange chauffé à haute température, après son expansion au sortir de la tuyère pénètre dans la turbine à une température que la machine peut facilement supporter. Les fluides élastiques après avoir traversé le rotor et lui avoir communiqué une partie de leur énergie cinétique s'échappent par des orifices d'évacuation et peuvent encore servir à réchauffer l'eau d'alimentation, le combustible et même l'air si on le désire. S'ils sont préalablement fortement chauffés, l'air et le combustible seront envoyés séparément dans la chambre de combustion ou dans le conduit, mais dans les petites installations il peut être convenable d'envoyer le combustible dans le compresseur ou le tuyau à air pour avoir un mélange intime du combustible. Quand la simplicité offre une certaine importance, on peut employer les réchauffeurs pour réaliser une économie, mais pour avoir une efficacité thermique encore plus considérable, il est fait usage d'un bouilleur dans lequel on fait circuler les fluides après leur sortie de la turbine. La vapeur ainsi obtenue au moyen de la chaleur perdue est envoyée par une valve convenable ouverte suivant la pression désirée dans un tuyau d'où elle passe avec le mélange de fluide moteur dans une tuyère et ainsi en premier lieu elle produit un travail utile et qui s'ajoute à celui de la chaleur perdue à l'échappement. Maintenant une plus grande quantité de combustible peut être graduellement admise pour maintenir une température normale dans le tuyau d'arrivée, ce qui augmente la chaleur de l'échappement et détermine une génération plus rapide de vapeur et ainsi de suite jusqu'à l'établissement d'un régime normal. Toutefois si on le trouve avantageux pour certains régimes, la quantité de vapeur fournie par l'équipement de l'appareil peut être réduite approximativement à celle fournie par le bouilleur.

L'invention va être décrite avec référence aux dessins annexés dans lesquels la fig. 1 montre le dispositif général de l'appareil qui comprend une turbine, un compresseur, un réservoir d'emmagasinement pour le combustible, un bouilleur et la tuyauterie nécessaire avec ses organes de commande et la fig. 2 est une coupe verticale de la valve principale d'admission de vapeur et de réglage de son écoulement.

Sur la première figure, 1 indique la turbine inventée par le demandeur dont l'arbre est accouplé élastiquement avec l'arbre de la machine à commander, par exemple une dynamo 2. La construction générale de la turbine est de préférence celle décrite dans le brevet français Tesla n° 421.543 du 17 octobre 1910 et il y a deux tuyères agissant dans la même direction. Les tuyères sont renfermées dans deux élargissements de l'enveloppe diamétralement opposés et communiquent avec les tuyaux d'arrivée 3 et 4 qui sont réunis par des valves convenables 5 et 6 à la valve principale d'admission et de réglage de vapeur 7 montrée en coupe sur la fig. 2 et qui sera décrite en détail.

Le compresseur d'air peut être d'un genre quelconque. Celui indiqué est du type à mouvement alternatif à grande vitesse. Il est actionné par un moteur électrique 8 et il est à deux étages 9 et 10 avec refroidisseur 11 intercalé. Un tuyau 12 muni d'une valve 13 connecte le conduit de décharge du compresseur aux conduits à bride 14 à 15 qui sont boulonnés avec les tuyaux d'arrivée 3 et 4 comme indiqué et sont munis de bougies électriques d'allumage 16 et 17. Un prolongement 18 du tuyau 12 conduit en passant par une valve 19 au-dessus du réservoir de combustible 20 et sert à le maintenir à la pression désirée. Lorsqu'on juge préférable d'employer un réservoir d'air il sera mis en communication avec le prolongement 18 du tuyau par une valve 21. Un tuyau d'alimentation 22 avec valve 23 est installé dans le haut du réservoir 20, tandis que près de son fond se trouve le tuyau de décharge 24 muni d'une valve 25 et ce dernier conduit par une valve à pointeau 26 à la valve automatique d'admission et de réglage de vapeur qui peut être manœuvrée automatiquement ou à la main.

Le fonctionnement se comprend facilement d'après ce qui vient d'être exposé. Au départ la valve 46 étant fermée et les valves 5 et 6 ouvertes, la vapeur est admise par la valve de réglage 7 dans les tuyaux 3 et 4 et de là aux tuyères d'où elle s'écoule avec une grande rapidité pour mettre le rotor en route et la machine fonctionne seulement comme une turbine à vapeur. Les bougies d'allumage 16 et 16 sont alors mises en jeu et les valves 13, 19 et 25 ouvertes, ce qui permet l'écoulement du combustible du réservoir, principalement par gravité, d'où il passe par la valve à pointeau 26 que l'on tourne graduellement. Le combustible passe par les orifices de la croix creuse 38, et les tuyaux 28 et 29 dans les appareils de mélange et de combustion dont la construction est montrée dans la coupe du branchement inférieur, étant entendu que l'arrangement du branchement supérieur est identique. Comme on le verra le conduit 15 est armé à une de ses extrémités d'un injecteur et à l'autre d'un prolongement en forme de lance qui est fixé entre les brides des tuyaux et qui s'engage assez loin dans le tuyau d'arrivée de vapeur 4. Le combustible atomisé par l'irruption de l'air entre dans la chambre de combustion constituée par l'élargissement du conduit 15 et y est enflammé, les produits de la combustion s'échappent dans le tuyau 4 et se mélangent avec la vapeur en se rendant à la tuyère. Ce genre d'appareil écarte la difficulté jusqu'à présent rencontrée dans les essais pour effectuer pratiquement la combustion et fonctionne avec satisfaction, même s'il y a des fluctuations considérables dans les pressions de la vapeur et de l'air parce que le fluide qui se meut plus rapidement aspire le fluide à écoulement plus lent. On a supposé que le combustible employé est liquide, mais on peut également employer du charbon en poudre d'une manière analogue avec quelques légères modifications de construction. La poussière de charbon est envoyée dans la chambre de combustion soit indépendamment, soit mélangée avec l'air. La quantité de combustible est réglée par la manœuvre des valves 13 et 26 (et également 5 et 6 et au besoin la valve de réglage 7) de telle façon que le mélange au sortir des tuyères se trouve à une température considérée comme non dommageable pour le fonctionnement de la turbine. Pour la facilité, on peut employer une valve compound d'un système connu pour admettre toujours les combustibles dans les proportions requises indépendamment de leur quantité totale.

Lorsque la vapeur du bouilleur 39 développée par le mélange gazeux d'échappement passant par les tubes, a atteint la pression requise, elle passe par la valve 46, le conduit 3 et la tuyère correspondante qui l'admet au rotor avec adjonction d'énergie cinétique. L'eau d'alimentation, de préférence chauffée par les gaz d'échappement de la turbine est retournée au bouilleur en proportion correspondante à la vapeur extraite. On emploiera pour cela les moyens ordinaires. Si on le trouve plus convenable ou avantageux on peut supprimer la connexion 45 au tuyau d'arrivée 3, la vapeur sera conduite au tuyau principal d'alimentation 34 et de là admise à la turbine comme décrit.

Le contrôle automatique de l'écoulement de la vapeur et du combustible peut être effectué au moyen d'un régulateur de vitesse connecté à la tige 37 et ainsi l'alimentation est réduite en même temps que l'accroissement de la vitesse. En plus de ces divers moyens, on peut employer une valve à air actionnée automatiquement par le régulateur de vitesse, soit par la tige 37 ou autrement. Pour plus de facilité en vue de permettre la commande indépendante de l'admission d'air et de combustible dans les deux branchements, on peut munir de valves les conduits 14, 15 et les tuyaux 28, 29, indiqués sur la fig. 1, leur dénombrement étant inutile.

La puissance fournie par le bouilleur 39 variera suivant les cas particuliers. Les turbines Tesla du brevet français n° 421.543 sont capables de fonctionner à une température d'échappement très élevée et l'énergie récupérée de la chaleur perdue peut constituer une large fraction de la totalité du travail utilisé. En pareil cas, on peut supprimer le conduit 3, les tuyaux 14 et 28 avec leurs accessoires et envoyer directement la vapeur à la tuyère par la valve 46. Ou bien on peut ne pas modifier ces connexions et leurs accessoires et installer une tuyère séparée. En admettant la vapeur du bouilleur au rotor de la turbine par des canaux indépendants, l'avantage pratique qui en résulte est que la pression peut varier considérablement sans influer beaucoup sur l'efficacité de la machine et qui sera encore améliorée en chauffant préalablement les combustibles par les procédés bien connus.

Cette installation permet d'avoir une turbine fonctionnant bien avec les fluides mélangés et démarrant d'elle-même. On peut aussi la faire marcher seulement à la vapeur en coupant l'admission d'air et de combustible et à ce point de vue elle est très avantageuse. On peut apporter diverses modifications de moindre importance suggérées par les cas particuliers, mais en suivant les indications générales on trouvera que ce système est très profitable aux propriétaires d'installations à vapeur déjà existantes en leur permettant d'en tirer un parti avantageux. Toutefois les résultats économiques procurés par la vapeur employée suivant le procédé de l'invention pour donner de la force motrice justifient des installations nouvelles. On ajoutera que le procédé peut aussi être employé avec succès dans les installations de condenseurs où on produit un vide élevé. La production et le maintien du vide seront facilités par l'emploi d'une pompe du genre décrit dans le brevet français Tesla auquel on s'est déjà référé. Dans ce cas en raison du très grand degré d'expansion le mélange à l'échappement sera à une température relativement basse et propice à l'admission au condenseur. Cela nécessitera de meilleur combustible et des facilités spéciales de pompage, mais les résultats économiques obtenus justifieront pleinement l'augmentation de dépenses d'installation.

RÉSUMÉ.

L'invention a pour objet d'augmenter l'efficacité d'une turbine en employant la vapeur comme force motrice. Elle comprend :

1° Un procédé dans lequel le rotor de la turbine est d'abord actionné par la vapeur seule et dont l'actionnement est continué par la vapeur mélangée en proportions convenables avec des produits de combustion de l'air et d'un combustible qui la surchauffent, la vapeur servant à contrôler la température du mélange qui sera sans danger pour la turbine et l'utilisation de la chaleur des gaz sortant de la turbine pour augmenter la production de vapeur.

2° La combinaison des divers éléments de l'appareil pour la mise à exécution du procédé.

NIKOLA TESLA.

Par procuration :

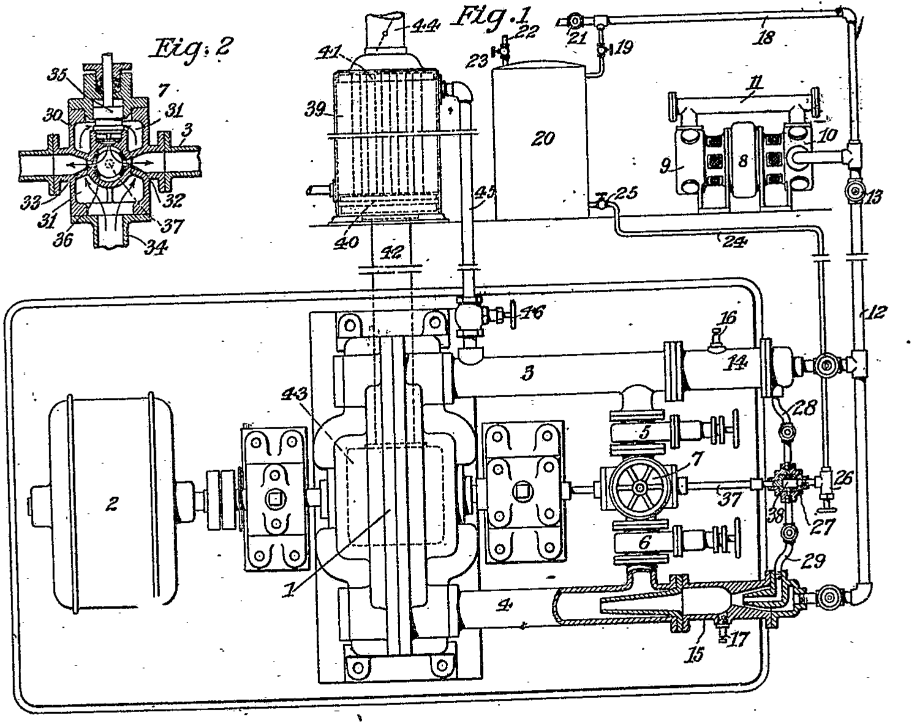
Louis TAILFER.

Pour la vente des fascicules, s'adresser à l'IMPRIMERIE NATIONALE, 87, rue Vieille-du-Temple. Paris (3e).

N° 549.259 M. Tesla Pl. unique

Fig: 2

Fig. 1



RÉPUBLIQUE FRANÇAISE.

OFFICE NATIONAL DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

V. — Machines.
5. — Machines diverses.

N° 549.261

Procédé et appareil pour la production d'un vide élevé.

M. Nikola TESLA résidant aux États-Unis d'Amérique.

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Dans la production de force par moteur thermodynamique, par exemple, les machines et les turbines à vapeur il est nécessaire d'avoir une basse contre-pression pour une bonne économie, car le rendement de la machine est augmenté de 50 à 100 % en réduisant la pression absolue dans la chambre d'échappement d'environ 1 kilog. à 0 kil. 07 par centimètre carré. Les turbines sont particulièrement susceptibles de s'adapter à ces perfectionnements et dans leur emploi dans les diverses branches de l'industrie pour procurer la force motrice, l'obtention et le maintien d'un haut degré de vide a pris une grande importance et des efforts ont été faits pour améliorer ces conditions. Dans une large mesure le gain obtenu dans cette voie dépend de la pression initiale des caractéristiques du moteur, de la température du milieu réfrigérant, du prix de l'appareil de condensation et de beaucoup d'autres choses bien connues des experts en la matière. L'économie théorique de 5 à 6 % de combustible pour chaque 2 cm. 5 additionnel de vide est souvent presque réalisée dans les installations modernes, mais les avantages économiques sont diminués d'une façon appréciable lorsqu'un vide élevé est appliqué aux machines existantes calculées pour travailler sous des vides moins élevés. Cela est surtout vrai quand il s'agit d'une turbine dans laquelle la réduction de la contre-pression augmente seulement la rapidité de l'échappement des vapeurs sans augmenter sensiblement la vitesse de leur impulsion contre les ailettes ou autres organes équivalents lorsque la perte d'énergie cinétique dans l'échappement peut absorber une partie considérable du travail utile. En pareil cas, il y a lieu d'opérer quelques changements dans la construction de la turbine et ses accessoires pour obtenir les résultats exposés, mais la dépense supplémentaire pour arriver à ce but sera engagée avec profit. En présence de cette situation on peut généralement admettre qu'on peut obtenir une réduction plus ou moins importante de la dépense du combustible dans la plupart des machines motrices existantes par l'adoption d'appareils appropriés faisant fonction de pompes et la réalisation de conditions de travail correspondant presque à celles d'un condenseur idéal.

La principale difficulté que l'on a rencontrée dans l'avancement de cette question vient des volumes énormes d'air et de vapeur à très basses pressions aussi bien que des fuites inévitables au condenseur, aux joints de tuyaux, des valves et des presse-garnitures. Actuellement un certain degré de vide est obtenu au moyen de pompes à mouvement alternatif et en raison de la vitesse nécessairement faible des pistons, ces pompes sont volumineuses et si les fuites sont importantes, elles sont incapables de donner satisfaction. Il résulte directement de cela que la machine de condensation est à la fois volumineuse et coûteuse et ce qui est encore pis, sa taille et son prix de revient augmentent d'une façon tout à fait disproportionnée en regard des résultats obtenus. Pour donner un exemple, le coût d'un appareil de condensation donnant 0 m. 710 de vide est environ le double d'un appareil donnant 0 m. 660 de vide et ces inconvénients sont encore accentués avec une réduction plus élevée de la contre-pression. Des pompes rotatives et des jets d'eau et de vapeur ont aussi été employés pour la production du vide, mais sans avantage bien marquants.

Le demandeur du brevet a obtenu plus de succès en s'éloignant de la méthode ordinaire qui consiste à enlever l'air et la vapeur entraînée du condenseur par des appareils tels que injecteurs, pompes à pistons ou rotatives et en appliquant les propriétés d'adhésion et de viscosité, qui, ainsi que cela a été montré par l'expérience, sont conservées par les gaz et les vapeurs même à un très haut degré de dilution. Ce nouveau procédé est rendu pratique au moyen d'une pompe, le principe en a été complètement expliqué dans le brevet français Tesla n° 421.543, du 17 octobre 1910, mais cette pompe est modifiée comme cela va être décrit dans la suite et lorsqu'elle tourne à une très grande vitesse périphérique dont est capable un système qui n'est pas chargé, elle fait preuve de deux propriétés remarquables et de grande valeur. L'une consiste dans l'expulsion du fluide raréfié à un degré si intense qu'un trou de quelque grandeur peut être fait dans le condenseur sans avoir beaucoup d'influence sur le degré de vide. L'autre consiste à extraire les fluides jusqu'à ce que le vide soit presque complet. Une machine de ce genre, construite en cascade, est seule suffisante pour la production d'un vide extrêmement élevé et cette qualité est estimée de grande valeur d'autant plus qu'elle n'est possédée au même degré par aucun autre type de pompe du commerce au moins à la connaissance de l'inventeur. On a aussi trouvé qu'une combinaison très efficace est obtenue en intercalant la pompe objet de l'invention entre le condenseur et une pompe dite « dry air » ou toute autre pompe. Cette combinaison est spécialement avantageuse au point de vue pratique parce qu'elle peut donner de bons résultats en une seule étape et que l'installation du système de l'invention ne demande que de légers changements dans l'ensemble de l'installation. Les avantages qui en dérivent sont doubles : un vide plus élevé est atteint et ce qui peut être encore plus important, les fréquentes et inévitables défectuosités qui affectent sérieusement l'économie, sont virtuellement éliminées. La pompe de l'invention rend possible le maintien d'un vide élevé même lorsque le pourcentage d'air ou autres fluides entraînés axec la vapeur est très grand et cet avantage est particulièrement important pour les turbines à fluides mélangés.

L'invention va être décrite avec référence aux dessins annexés dans lesquels la fig. 1 est une vue en coupe de la pompe conjuguée et la fig. 2 montre cette même pompe combinée avec une pompe à piston à double action.

Sur la première figure 1, 2 . . . sont des rotors dont chacun tels que 1, comprend un certain nombre de disques relativement minces 3, 3 . . . . séparés par des rondelles étoilées 4, 4, et maintenues ensemble par des plaques d'extrémités rigides 5 et 6 sur un manchon 7 qui est ajusté et claveté sur l'arbre 8 porté par des paliers 9, 9. Les rotors sont renfermés dans les chambres séparées d'un bâti commun 10 formant enveloppe et dont les diverses parties munies de rebords sont boulonnées ensemble. En partant du premier compartiment en 1, les rotors vont en diminuant de largeur, chaque rotor étant plus étroit que le précédent pour des raisons économiques évidentes. Tous les disques minces tels que 3, 3, et les plaques d'extrémité de gauche, telles que 5 sont munies des ouvertures centrales ordinaires, mais les plaques d'extrémité de droite, telles que 6, sont pleines. Les chambres individuelles contenant les rotors communiquent l'une avec l'autre par des canaux tels que 11 allant de la périphérie d'une chambre à la partie centrale de la suivante de telle façon que les fluides aspirés par les conduites d'entrée 12, 12 sont forcés de passer à travers toute la série des rotors et sont finalement injectés par l'ouverture à bride 13 de la dernière chambre. Pour diminuer les fuites le long de l'arbre, on emploie des joints ou garnitures étanches 14 qui peuvent être établis ainsi que cela se pratique ordinairement et qu'il est inutile de décrire. Le nombre de compartiments dépend de la vitesse périphérique et du degré de vide que l'on désire atteindre et dans les cas extrêmes on peut avoir recours à plusieurs appareils séparés ayant un arbre commun avec paliers intermédiaires de support. Lorsqu'on le trouve préférable, la pompe peut être du type à double écoulement, lorsqu'il n'y a pas de poussée latérale appréciable, autrement on prendra des dispositions pour y résister.

Les modifications dans les détails de construction dont il est question, consistent à employer de plus petits espaces entre les disques que cela n'a été fait jusqu'à présent, et en laissant peu d'espace entre les disques extérieurs et les enveloppes. Pour donner un exemple il sera indiqué que des espaces d'environ 1 millimètre entre les disques sont efficaces pour obtenir un vide très élevé avec des disques de 600 millimètres de diamètre. On emploie aussi des disques à surfaces inclinées du centre vers la périphérie lorsque cela est nécessaire afin de faire marcher l'appareil avec sécurité à une très grande vitesse périphérique ce qui est très désirable sous le rapport de l'encombrement et de l'efficacité de la machine.

Le dispositif représenté schématiquement fig. 2 est spécialement convenable et avantageux pour être employé avec les machines à vapeur existantes fonctionnant avec un haut degré de vide et il permet l'application des perfectionnements de l'invention d'une manière simple et économique. Dans ce cas la pompe qui peut comporter un seul rotor du genre décrit précédemment est connectée avec l'orifice d'entrée 12 par un tuyau 15 monté sur le dessus du condenseur 16 et l'orifice de sortie 13 de la turbine est connecté par un tuyau 17 au conduit d'aspiration d'une pompe à air 18 à mouvement alternatif. Il va sans dire que dans la pratique, les connections 15 et 17 seront courtes et d'une très grande section, parce qu'il y a à pomper un volume énorme de fluide.

D'après ce qui a été dit, le fonctionnement sera facile à comprendre. Les orifices d'entrée 12 (fig. 1) étant connectées avec des joints bien étanches avec le récipient à vider et l'appareil à disques tournant à une très grande vitesse périphérique, les fluides par suite de leurs propriétés de viscosité et d'adhésion sont soutirés du récipient jusqu'à ce qu'on ait obtenu le degré de raréfaction pour lequel l'appareil a été construit. Dans leur passage à travers les séries de rotors, les fluides sont comprimés par étapes et éjectés par l'ouverture 13 à un volume très réduit. Le vide obtenu par ces moyens peut être extrêmement élevé en raison des propriétés apparemment uniques du système décrit. Comme les fluides sont aspirés à une très grande vitesse, quelle que soit leur densité, les fuites par les joints, presse-garnitures et autres connexions sont sans importance sensible.

Dans le dispositif montré sur la fig. 2 la pompe de l'invention sert à faire le vide au condenseur beaucoup plus efficacement et en comprimant les fluides à leur entrée dans la pompe à pistons, elle augmente l'efficacité de cette dernière. L'installation du système de l'invention pour le combiner avec des machines existantes nécessite peu de changements et procure une économie notable de combustible. La pompe de l'invention peut aussi être avantageusement employée au lieu d'un éjecteur à vapeur en combinaison avec un petit condenseur, en ce cas ses dimensions sont insignifiantes et elle consomme peu de vapeur.

RÉSUMÉ :

L'invention a pour objet :

1° Un procédé de raréfaction des gaz et vapeurs qui consiste à mettre le récipient en communication avec un appareil constitué par un rotor à disques et à éjecter d'une façon continue le fluide adhérent aux disques du rotor jusqu'à ce qu'on ait obtenu un vide élevé dans le récipient;

2° Pour faire le vide dans le récipient, l'utilisation de la force de friction provenant de la viscosité du fluide et de son adhésion aux disques du rotor;

3° Pour faire le vide dans un récipient le procédé de raréfaction consistant à aspirer de ce récipient les fluides atténués en utilisant la forme de friction du système à disques tournants, à les comprimer pendant leur passage dans l'appareil à la sortie duquel ils sont pris par une pompe;

La combinaison des divers appareils pour obtenir un vide élevé.

Nikola TESLA.

Par procuration :

Louis Tailfer.

N° 549.261 M. Tesla Pl. unique

Fig. 1

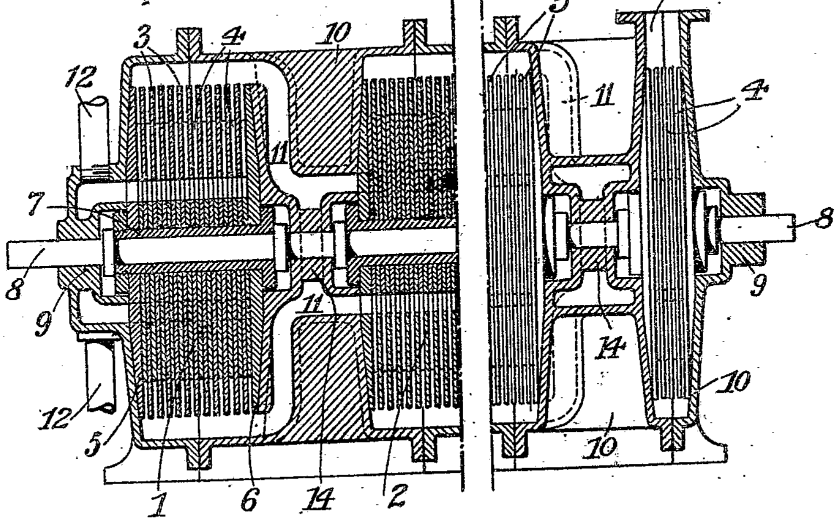
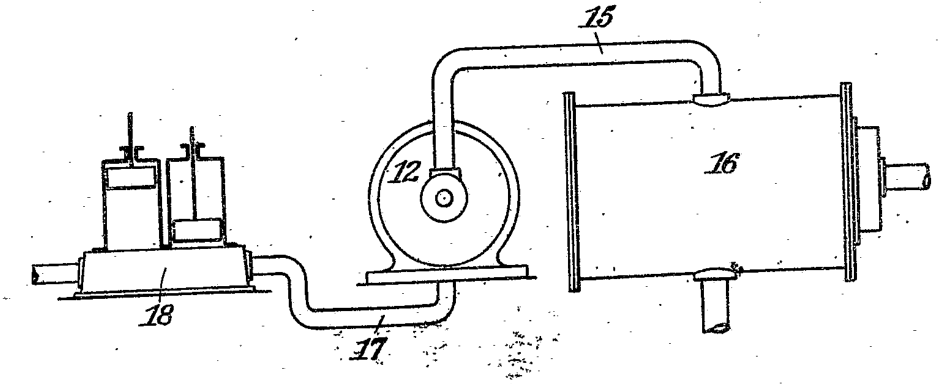


Fig. 2



[Second Edition.]

PATENT SPECIFICATION

Application Date: Apr. 1, 1921. No. 9729/21.
Complete Left: Sept. 2, 1921.
Complete Accepted: Feb. 2, 1922.

174,544

PROVISIONAL SPECIFICATION.

Improvements in Methods of and Apparatus for the Generation of Power by Elastic Fluid Turbines.

I, NIKOLA TESLA, Mechanical and Electrical Engineer, citizen of the United States of America, of 8, West 40th Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

In the transformation of the heat of elastic media, by means of turbines, two methods are now extensively employed. In one, the working fluid is expanded through a stationary nozzle and the free jet, impinging against vanes or equivalent devices integral with the rotor, gives up to it velocity energy, thus setting it in motion by action. In the other, the fluid is admitted at full pressure to curved blades or channels in the rotor where it expands imparting energy to the same and causing it to turn by reaction. For well-known technical reasons turbines operating purely on either the first or the second principle are scarcely ever used, both processes being jointly applied in modern machines. Furthermore, almost invariably staging is resorted to with the object of subdividing the velocity- and pressure-drop and improving thereby the performance in conformity with fundamental laws of propulsion.

As is obvious from theoretical considerations and heat diagrams, the reaction turbine with pressure stages is generally capable of a higher thermodynamic efficiency because it has a bigger "reheat factor", that is to say, it transforms into mechanical effort a considerably larger portion of friction heat than recovered in the action turbine, with velocity stages. On the other hand, it will be equally apparent that the former is more limited in the temperature range and, in view of this handicap, its superiority would not be so pronounced were it not for the fact that the relative velocity of the fluid is greater in the latter turbine, this detracting still more from its efficiency.

These respective qualities and shortcomings have been fully recognized by engineers long ago and have gradually led to the employment of impulse- and reaction-wheels merged into one unit which is thus better adapted for meeting the requirements and should be more economical. But although this idea seems sound, the temperature range has not been very much increased through its application and the gain, so far effected, is moderate indeed, to the point of being doubtful in many instances. Definite limits to progress in this direction have been reached in the existing commercial apparatus and the discovery of other ways and means for saving fuel and reducing the cost of installment and operation has become a problem rendered especially pressing throughout the world by the greatly increased cost of this commodity.

The advantages of the action and reaction principles can be more completely realized through a process which constitutes my present invention and, briefly stated, consists in deriving motive power from the heat of an elastic medium first by means of friction and then by reaction. The best instrumentalities for the purpose, of which I am aware, are a turbine of the kind described in my British Patent No. 24,001 of 1910 and one of the Parsons type, both being connected or worked independently. The

[*Price* 1*s*.]

fluid is admitted to my turbine through a suitable nozzle which may be expanding, straight or converging, and in traversing the spaces between the disks exercises a frictional drag, thus transforming a part of the available heat into mechanical work. Upon exhausting under proper temperature and pressure conditions it is passed through the Parsons turbine in which another portion of its caloric energy is usefully converted by reaction. Careful scientific investigation, supported by experiment, has shown that important economic results can be secured by the new method and that this particular combination of apparatus possesses features of unusual merit.

In the first place my turbine is exceedingly suited for very elevated temperatures and also high pressures, while the Parsons excels in the efficiency of the thermo-dynamic transformation at moderate temperatures and low pressures. Again, the former permits the fluid to be expanded either in the nozzle, the rotor or both, and this flexibility facilitates the establishment and maintenance of pressure and temperature conditions favorable to both turbines, thus enhancing economy. Their combination is, however, of quite exceptional value in cases when reversible units are indispensable, as on shipboard, where it provides a simpler, more efficient and far more effective apparatus for forward propulsion as well as backing, my turbine being much better adapted for reversing purposes than other forms with small clearances and delicate blading easily damaged.

While my turbine will yield the best results in co-operation with the Parsons it is eminently qualified to serve as first stage, or stages, in conjunction with other types of turbines, of whatever kind, also with rotating and reciprocating engines, and in this broader sense my improved process may be defined as one in which the available heat of an elastic medium is usefully transformed first by friction, as indicated, and then by action or reaction.

Dated this 31st day of March, 1921.
NIKOLA TESLA.

COMPLETE SPECIFICATION.

Improvements in Methods of and Apparatus for the Generation of Power by Elastic Fluid Turbines.

I, Nikola Tesla, Electrical and Mechanical Engineer, citizen of the United States of America, of 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In the transformation of the heat energy of elastic media, by means of turbines, two methods are now extensively employed. In one, the working fluid is expanded through a stationary nozzle and the free jet, impinging against vanes or equivalent devices integral with the rotor, gives up to it velocity energy, thus setting it in motion by action. In the other, the fluid is admitted at full pressure to curved blades or channels in the rotor where it expands imparting energy to the same and causing it to turn by reaction. For well-known technical reasons turbines operating purely on either the first or the second principle are scarcely ever used, both processes being jointly applied in modern machines. Furthermore, almost invariably staging is resorted to with the object of subdividing the velocity- and pressure-drop and improving thereby the performance in conformity with fundamental laws of propulsion.

As is obvious from theoretical consideration and heat diagrams, the reaction turbine with pressure stages is generally capable of a higher thermodynamic efficiency because it has a bigger "reheat factor", that is to say, it transforms into mechanical effort a considerably larger portion of friction heat than is recovered in the action turbine, with velocity stages. On the other hand, it will be equally apparent that the former is more limited in the temperature range and, in view of this handicap, its superiority would not be so pronounced were it not for the fact that usually the relative velocity of the fluid is greater in the latter turbine, this detracting still more from its efficiency.

These respective qualities and shortcomings have been long recognized by engineers and have gradually led to the employment of impulse and reaction-wheels merged into one unit which is thus better adapted for meeting the requirements and should be more economical. But although this idea seems sound, the temperature range has not been very much increased through its application and the gain, so far effected, is moderate indeed, to the point of being doubtful in many instances. Definite limits to progress in this direction have been reached in the existing commercial apparatus and the discovery of other ways and means for saving fuel and reducing the cost of installation has become a problem rendered especially pressing throughout the world by the greatly increased cost of this commodity.

The economic advantages contemplated can be more completely realized through a process which constitutes my present invention and, briefly stated, consists in converting part of the heat energy of an elastic medium into mechanical work by friction, preferably at a high temperature, and a further part by action or reaction at a lower temperature. The best instrumentalities for the purpose, of which I am aware, are a friction turbine of the kind described in my British Patent No. 24,001 of 1910 and one of the reaction type, such as the Parsons, both being connected or worked independently. The fluid is admitted to my turbine through a suitable nozzle which may be expanding, straight or converging, and in traversing the spaces between the discs exercises a frictional drag, thus transforming a part of the available heat energy into mechanical work. Upon exhausting under proper temperature and pressure conditions it is passed through the reaction turbine in which another portion of its caloric energy is usefully converted by reaction.

In the accompanying drawings Fig. 1 is intended to represent my improved turbine and one of the Parsons type operatively joined and with their shafts flexibly connected; Fig. 2 is a plan view of the same with supply conduits and inlet valves, and Fig. 3 a vertical cross-section of my turbine.

Referring to the figures, 1 illustrates the rotor of my turbine enclosed in a casing 2, 2, provided with two inlets 3, 3 for the working medium, nozzles 4 and 5 —one for normal operation and the other for reversal—and two exhaust openings 6, 6 which lead through a conduit 7 to the intake 8 and slide valve 9 of the Parsons turbine 10. The exhaust 11 of the latter communicates through a conduit 12 with the condenser to which is also connected a by-pass 13, branching out from exhaust pipe 7 and equipped with a valve 14. A throttle valve 15 controls the admission of the elastic fluid to my turbine which has, besides, two suitable valves 16 and 17, preferably joined by mechanical means as chain 18, enabling them to be turned together so that one will be closed tight while the other is wide open.

In normal operation valves 17 and 14 are closed and the medium is admitted to my turbine through valves 15, 16 and nozzle 4, whence it passes through the rotor 1, exhaust openings 6, 6 and pipe 7 to the intake 8 and valve 9 of the Parsons turbine 10 and, after traversing the same, is discharged through exhaust 11 and conduit 12 into the condenser, under which conditions both the turbines are actuated in the same direction, rotation taking place in the sense of the solid arrow Fig. 3. When it is desired to operate in the reverse direction (indicated by the dotted arrow), valves 16 and 9 are closed and 17 and 14 opened wide, the medium entering my turbine through nozzle 5, and after passing through the rotor 1, exhaust openings 6, 6, pipe 7 and by-pass 13, discharges into the condenser. The Parsons turbine is then driven in a direction opposite to its blading but offers a relatively small resistance owing to the vacuum therein; my turbine, on the other hand, develops an amount of power much greater than when working as first described on account of its direct connection with the condenser and correspondingly increased heat drop.

Careful scientific investigation, supported by experiment, has shown that important economic results can be secured by the new method and that this particular combination of apparatus possesses features of unusual merit.

In the first place my turbine is especially suited for very elevated temperatures and also high pressures, while the Parsons is particularly adapted to thermo-dynamic transformation at moderate temperatures and low pressures. Again, the former permits the fluid to be expanded either in the nozzle, the rotor or both, and this flexibility facilitates the establishment and maintenance of pressure and temperature conditions favorable to both turbines, thus enhancing economy. Their combination is, however, of quite exceptional value in cases when reversible units are indispensable, as on shipboard, where it provides a simpler and more effective apparatus for forward propulsion as well as backing, my turbine being much more dependable than the present forms with buckets and blades which are very liable to deterioration and easily damaged.

In the use of different types, as here contemplated, the individual heat drops in them may be considerably varied in magnitude, but to give a practical example I would say that very good results, when working with superheated steam alone, are obtainable by admitting the steam to the nozzle of the friction turbine at about 1100° F. and exhausting it at approximately 550° F. into a reaction turbine capable of operating safely at that temperature.

While my turbine in such combinations will yield the best results in co-operation with the Parsons, it is eminently qualified to serve as first stage, or stages, in conjunction with other types of turbines, of whatever kind; also with rotary and reciprocating engines, and in this broader sense my improved process may be defined as one in which the available heat energy of an elastic fluid is usefully transformed first by friction, as indicated, and then by action or reaction.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is :—

1. The improved method of thermodynamic transformation which consists in converting a part of the heat energy of an elastic fluid by disc friction and a further part by blade action, substantially as described.

2. The hereinbefore described process of transforming the heat energy of an elastic fluid into rotary mechanical work which consists in converting a part of the energy of the fluid by friction at high temperature and a further part by action and/or reaction at a lower temperature, substantially as described.

3. In the conversion of heat energy of elastic fluids the combination of the friction and reaction type of turbine, as described.

4. The combined use of a friction turbine of the kind described with an action and reaction engine in the transformation of the heat energy of elastic fluids into mechanical work.

5. The combination of a friction turbine of the type described with a turbine of the reaction type mounted on the same shaft or on connected shafts to form an operative unit for the transformation of the heat energy of elastic fluids into mechanical work.

6. The combination of a friction and a reaction turbine of the types described connected to form a power unit so that both may operate together in one direction or be driven in the opposite direction by the friction turbine, the reaction turbine running idle, as described.

Dated the 23rd day of August, 1921.

NIKOLA TESLA.

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[Wt. 70—125/10/1923.]

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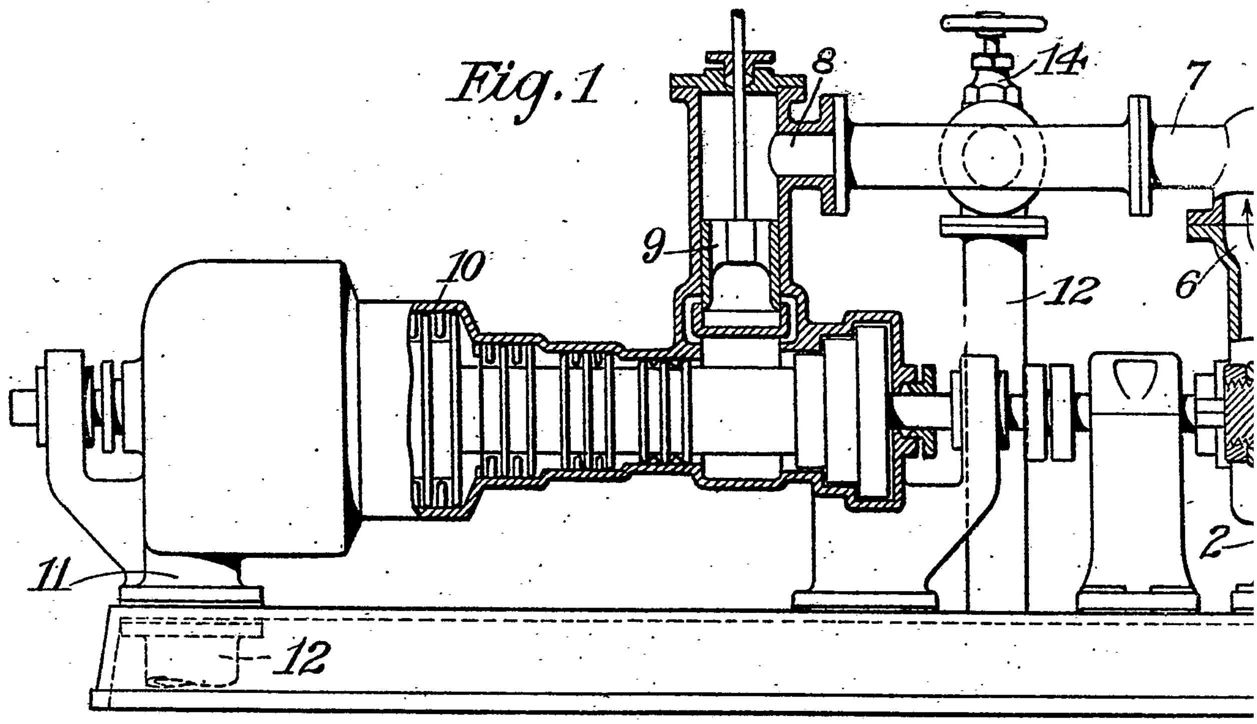
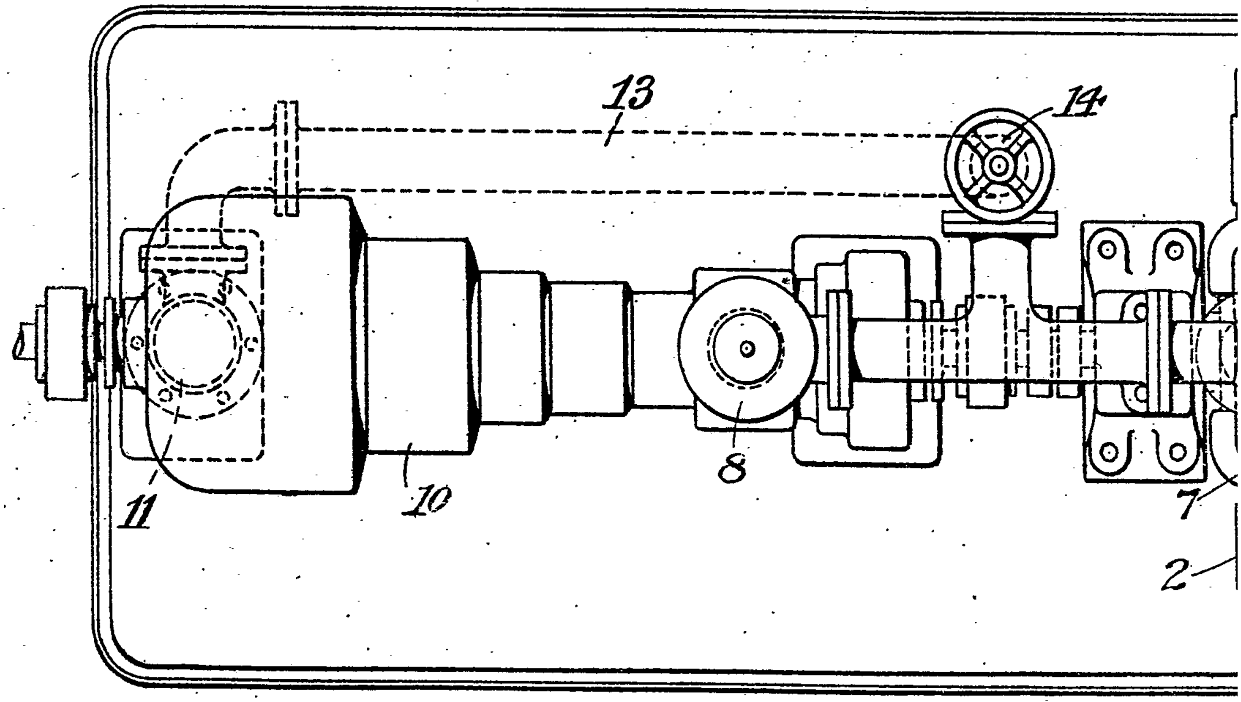
Fig. 1





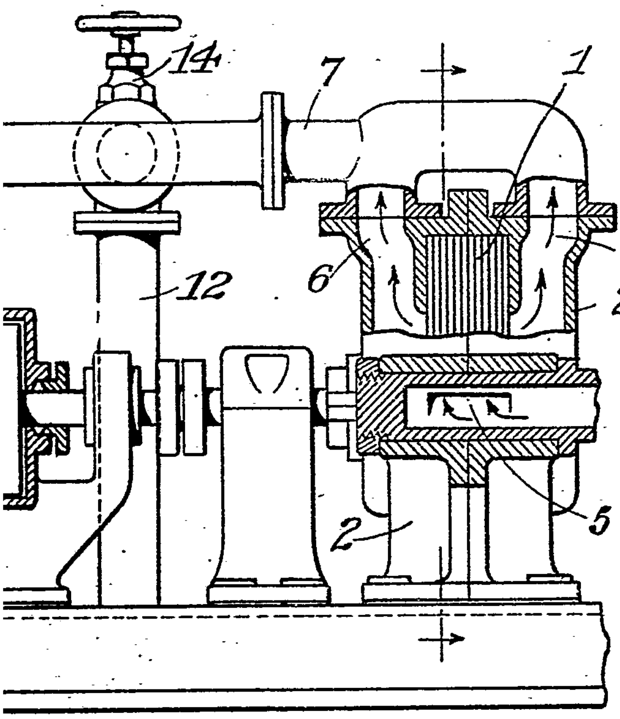


Fig. 3

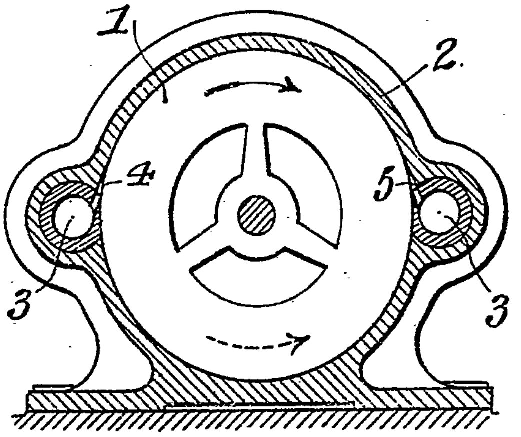


Fig. 2

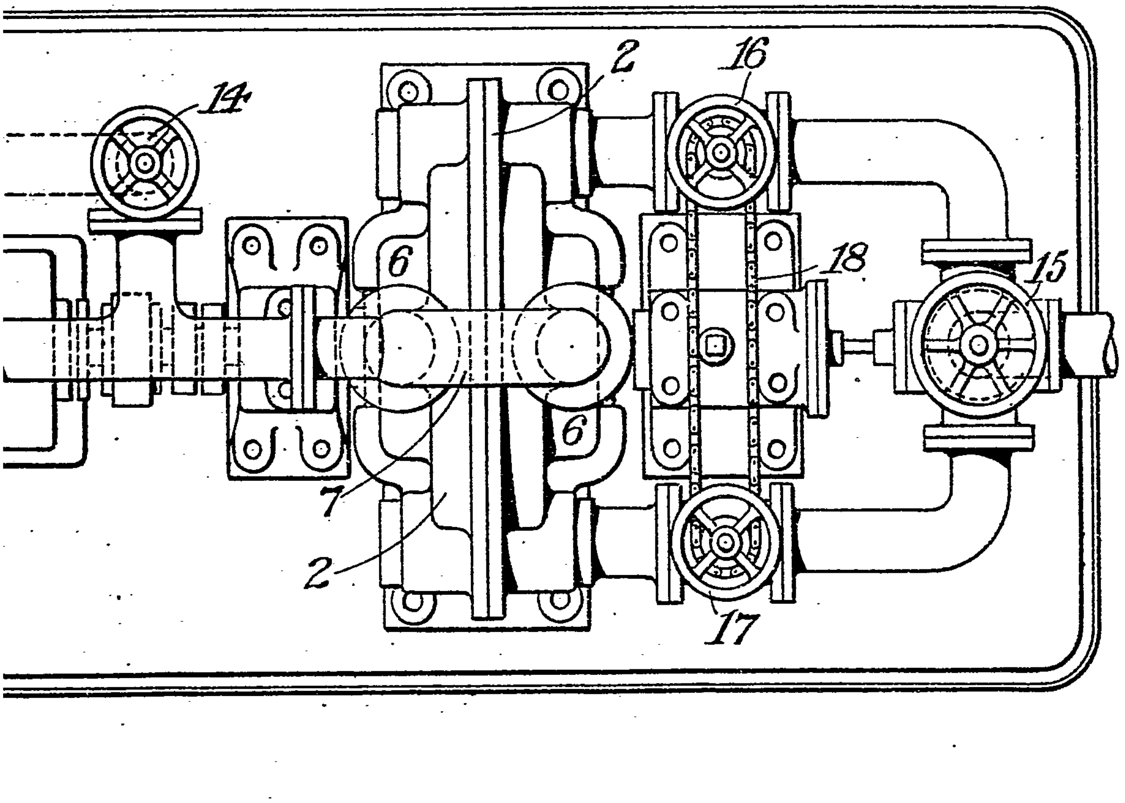


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Fig. 1

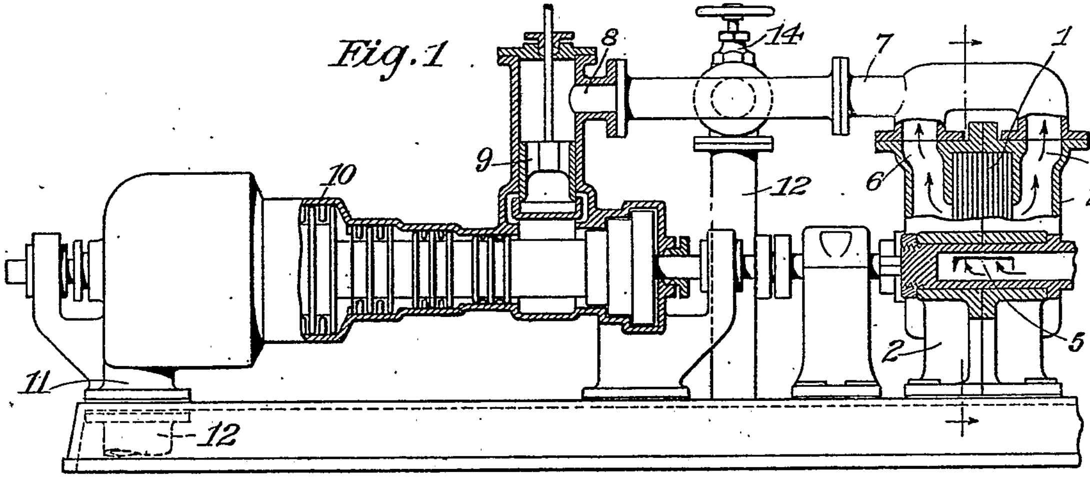


Fig. 3

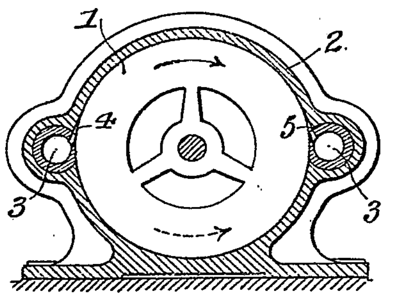
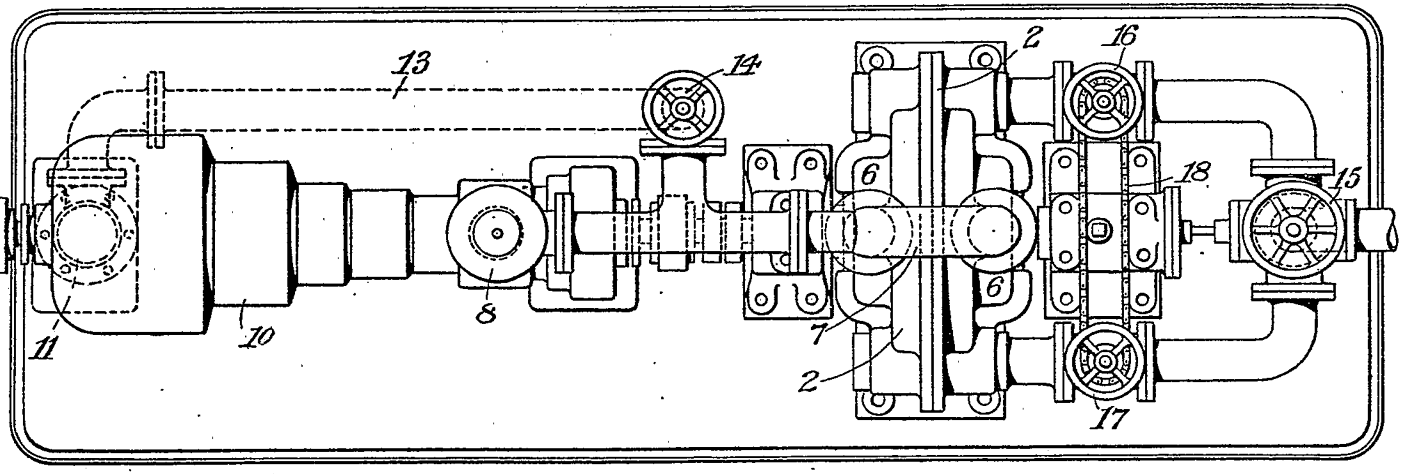


Fig. 2



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[Second Edition.]

PATENT SPECIFICATION

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Complete Left: Sept. 2, 1921.
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I, Nikola Tesla, Mechanical and Electrical Engineer, citizen of the United States of America, of 8, West 40th Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

In the transformation of the heat of elastic media, by means of turbines, two methods are now extensively employed. In one, the working fluid is expanded through a stationary nozzle and the free jet, impinging against vanes or equivalent devices integral with the rotor, gives up to it velocity energy, thus setting it in motion by action. In the other, the fluid is admitted at full pressure to curved blades or channels in the rotor where it expands imparting energy to the same and causing it to turn by reaction. For well-known technical reasons turbines operating purely on either the first or the second principle are scarcely ever used, both processes being jointly applied in modern machines. Furthermore, almost invariably staging is resorted to with the object of subdividing the velocity- and pressure-drop and improving thereby the performance in conformity with fundamental laws of propulsion.

As is obvious from theoretical considerations and heat diagrams, the reaction turbine with pressure stages is generally capable of a higher thermodynamic efficiency because it has a bigger "reheat factor", that is to say, it transforms into mechanical effort a considerably larger portion of friction heat than recovered in the action turbine, with velocity stages. On the other hand, it will be equally apparent that the former is more limited in the temperature range and, in view of this handicap, its superiority would not be so pronounced were it not for the fact that the relative velocity of the fluid is greater in the latter turbine, this detracting still more from its efficiency.

These respective qualities and shortcomings have been fully recognized by engineers long ago and have gradually led to the employment of impulse- and reaction-wheels merged into one unit which is thus better adapted for meeting the requirements and should be more economical. But although this idea seems sound, the temperature range has not been very much increased through its application and the gain, so far effected, is moderate indeed, to the point of being doubtful in many instances. Definite limits to progress in this direction have been reached in the existing commercial apparatus and the discovery of other ways and means for saving fuel and reducing the cost of installment and operation has become a problem rendered especially pressing throughout the world by the greatly increased cost of this commodity.

The advantages of the action and reaction principles can be more completely realized through a process which constitutes my present invention and, briefly stated, consists in deriving motive power from the heat of an elastic medium first by means of friction and then by reaction. The best instrumentalities for the purpose, of which I am aware, are a turbine of the kind described in my British Patent No. 24,001 of 1910 and one of the Parsons type, both being connected or worked independently. The

[*Price* 1*s.*]

fluid is admitted to my turbine through a suitable nozzle which may be expanding, straight or converging, and in traversing the spaces between the disks exercises a frictional drag, thus transforming a part of the available heat into mechanical work. Upon exhausting under proper temperature and pressure conditions it is passed through the Parsons turbine in which another portion of its caloric energy is usefully converted by reaction. Careful scientific investigation, supported by experiment, has shown that important economic results can be secured by the new method and that this particular combination of apparatus possesses features of unusual merit.

In the first place my turbine is exceedingly suited for very elevated temperatures and also high pressures, while the Parsons excels in the efficiency of the thermo-dynamic transformation at moderate temperatures and low pressures. Again, the former permits the fluid to be expanded either in the nozzle, the rotor or both, and this flexibility facilitates the establishment and maintenance of pressure and temperature conditions favorable to both turbines, thus enhancing economy. Their combination is, however, of quite exceptional value in cases when reversible units are indispensable, as on shipboard, where it provides a simpler, more efficient and far more effective apparatus for forward propulsion as well as backing, my turbine being much better adapted for reversing purposes than other forms with small clearances and delicate blading easily damaged.

While my turbine will yield the best results in co-operation with the Parsons it is eminently qualified to serve as first stage, or stages, in conjunction with other types of turbines, of whatever kind, also with rotating and reciprocating engines, and in this broader sense my improved process may be defined as one in which the available heat of an elastic medium is usefully transformed first by friction, as indicated, and then by action or reaction.

Dated this 31st day of March, 1921.

NIKOLA TESLA.

COMPLETE SPECIFICATION.

Improvements in Methods of and Apparatus for the Generation of Power by Elastic Fluid Turbines.

I, Nikola Tesla, Electrical and Mechanical Engineer, citizen of the United States of America, of 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In the transformation of the heat energy of elastic media, by means of turbines, two methods are now extensively employed. In one, the working fluid is expanded through a stationary nozzle and the free jet, impinging against vanes or equivalent devices integral with the rotor, gives up to it velocity energy, thus setting it in motion by action. In the other, the fluid is admitted at full pressure to curved blades or channels in the rotor where it expands imparting energy to the same and causing it to turn by reaction. For well-known technical reasons turbines operating purely on either the first or the second principle are scarcely ever used, both processes being jointly applied in modern machines. Furthermore, almost invariably staging is resorted to with the object of subdividing the velocity- and pressure-drop and improving thereby the performance in conformity with fundamental laws of propulsion.

As is obvious from theoretical consideration and heat diagrams, the reaction turbine with pressure stages is generally capable of a higher thermodynamic efficiency because it has a bigger "reheat factor", that is to say, it transforms into mechanical effort a considerably larger portion of friction heat than is recovered in the action turbine, with velocity stages. On the other hand, it will be equally apparent that the former is more limited in the temperature range and, in view of this handicap, its superiority would not be so pronounced were it not for the fact that usually the relative velocity of the fluid is greater in the latter turbine, this detracting still more from its efficiency.

These respective qualities and shortcomings have been long recognized by engineers and have gradually led to the employment of impulse and reaction-wheels merged into one unit which is thus better adapted for meeting the requirements and should be more economical. But although this idea seems sound, the temperature range has not been very much increased through its application and the gain, so far effected, is moderate indeed, to the point of being doubtful in many instances. Definite limits to progress in this direction have been reached in the existing commercial apparatus and the discovery of other ways and means for saving fuel and reducing the cost of installation has become a problem rendered especially pressing throughout the world by the greatly increased cost of this commodity.

The economic advantages contemplated can be more completely realized through a process which constitutes my present invention and, briefly stated, consists in converting part of the heat energy of an elastic medium into mechanical work by friction, preferably at a high temperature, and a further part by action or reaction at a lower temperature. The best instrumentalities for the purpose, of which I am aware, are a friction turbine of the kind described in my British Patent No. 24,001 of 1910 and one of the reaction type, such as the Parsons, both being connected or worked independently. The fluid is admitted to my turbine through a suitable nozzle which may be expanding, straight or converging, and in traversing the spaces between the discs exercises a frictional drag, thus transforming a part of the available heat energy into mechanical work. Upon exhausting under proper temperature and pressure conditions it is passed through the reaction turbine in which another portion of its caloric energy is usefully converted by reaction.

In the accompanying drawings Fig. 1 is intended to represent my improved turbine and one of the Parsons type operatively joined and with their shafts flexibly connected; Fig. 2 is a plan view of the same with supply conduits and inlet valves, and Fig. 3 a vertical cross-section of my turbine.

Referring to the figures, 1 illustrates the rotor of my turbine enclosed in a casing 2, 2, provided with two inlets 3, 3 for the working medium, nozzles 4 and 5—one for normal operation and the other for reversal—and two exhaust openings 6, 6 which lead through a conduit 7 to the intake 8 and slide valve 9 of the Parsons turbine 10. The exhaust 11 of the latter communicates through a conduit 12 with the condenser to which is also connected a by-pass 13, branching out from exhaust pipe 7 and equipped with a valve 14. A throttle valve 15 controls the admission of the elastic fluid to my turbine which has, besides, two suitable valves 16 and 17, preferably joined by mechanical means as chain 18, enabling them to be turned together so that one will be closed tight while the other is wide open.

In normal operation valves 17 and 14 are closed and the medium is admitted to my turbine through valves 15, 16 and nozzle 4, whence it passes through the rotor 1, exhaust openings 6, 6 and pipe 7 to the intake 8 and valve 9 of the Parsons turbine 10 and, after traversing the same, is discharged through exhaust 11 and conduit 12 into the condenser, under which conditions both the turbines are actuated in the same direction, rotation taking place in the sense of the solid arrow Fig. 3. When it is desired to operate in the reverse direction (indicated by the dotted arrow), valves 16 and 9 are closed and 17 and 14 opened wide, the medium entering my turbine through nozzle 5, and after passing through the rotor 1, exhaust openings 6, 6, pipe 7 and by-pass 13, discharges into the condenser. The Parsons turbine is then driven in a direction opposite to its blading but offers a relatively small resistance owing to the vacuum therein; my turbine, on the other hand, develops an amount of power much greater than when working as first described on account of its direct connection with the condenser and correspondingly increased heat drop.

Careful scientific investigation, supported by experiment, has shown that important economic results can be secured by the new method and that this particular combination of apparatus possesses features of unusual merit.

In the first place my turbine is especially suited for very elevated temperatures and also high pressures, while the Parsons is particularly adapted to thermo-dynamic transformation at moderate temperatures and low pressures. Again, the former permits the fluid to be expanded either in the nozzle, the rotor or both, and this flexibility facilitates the establishment and maintenance of pressure and temperature conditions favorable to both turbines, thus enhancing economy. Their combination is, however, of quite exceptional value in cases when reversible units are indispensable, as on shipboard, where it provides a simpler and more effective apparatus for forward propulsion as well as backing, my turbine being much more dependable than the present forms with buckets and blades which are very liable to deterioration and easily damaged.

In the use of different types, as here contemplated, the individual heat drops in them may be considerably varied in magnitude, but to give a practical example I would say that very good results, when working with superheated steam alone, are obtainable by admitting the steam to the nozzle of the friction turbine at about 1100° F. and exhausting it at approximately 550° F. into a reaction turbine capable of operating safely at that temperature.

While my turbine in such combinations will yield the best results in co-operation with the Parsons, it is eminently qualified to serve as first stage, or stages, in conjunction with other types of turbines, of whatever kind; also with rotary and reciprocating engines, and in this broader sense my improved process may be defined as one in which the available heat energy of an elastic fluid is usefully transformed first by friction, as indicated, and then by action or reaction.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is :—

1. The improved method of thermodynamic transformation which consists in converting a part of the heat energy of an elastic fluid by disc friction and a further part by blade action, substantially as described.

2. The hereinbefore described process of transforming the heat energy of an elastic fluid into rotary mechanical work which consists in converting a part of the energy of the fluid by friction at high temperature and a further part by action and/or reaction at a lower temperature, substantially as described.

3. In the conversion of heat energy of elastic fluids the combination of the friction and reaction type of turbine, as described.

4. The combined use of a friction turbine of the kind described with an action and reaction engine in the transformation of the heat energy of elastic fluids into mechanical work.

5. The combination of a friction turbine of the type described with a turbine of the reaction type mounted on the same shaft or on connected shafts to form an operative unit for the transformation of the heat energy of elastic fluids into mechanical work.

6. The combination of a friction and a reaction turbine of the types described connected to form a power unit so that both may operate together in one direction or be driven in the opposite direction by the friction turbine, the reaction turbine running idle, as described.

Dated the 23rd day of August, 1921.

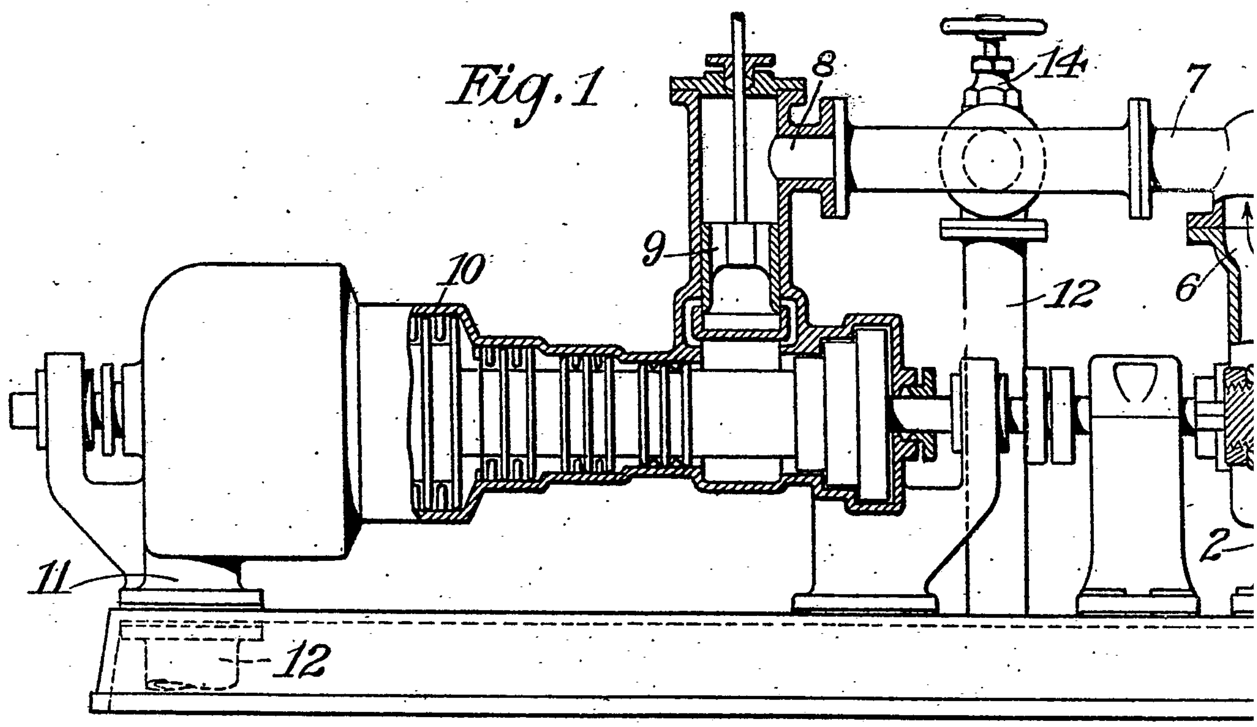
NIKOLA TESLA.

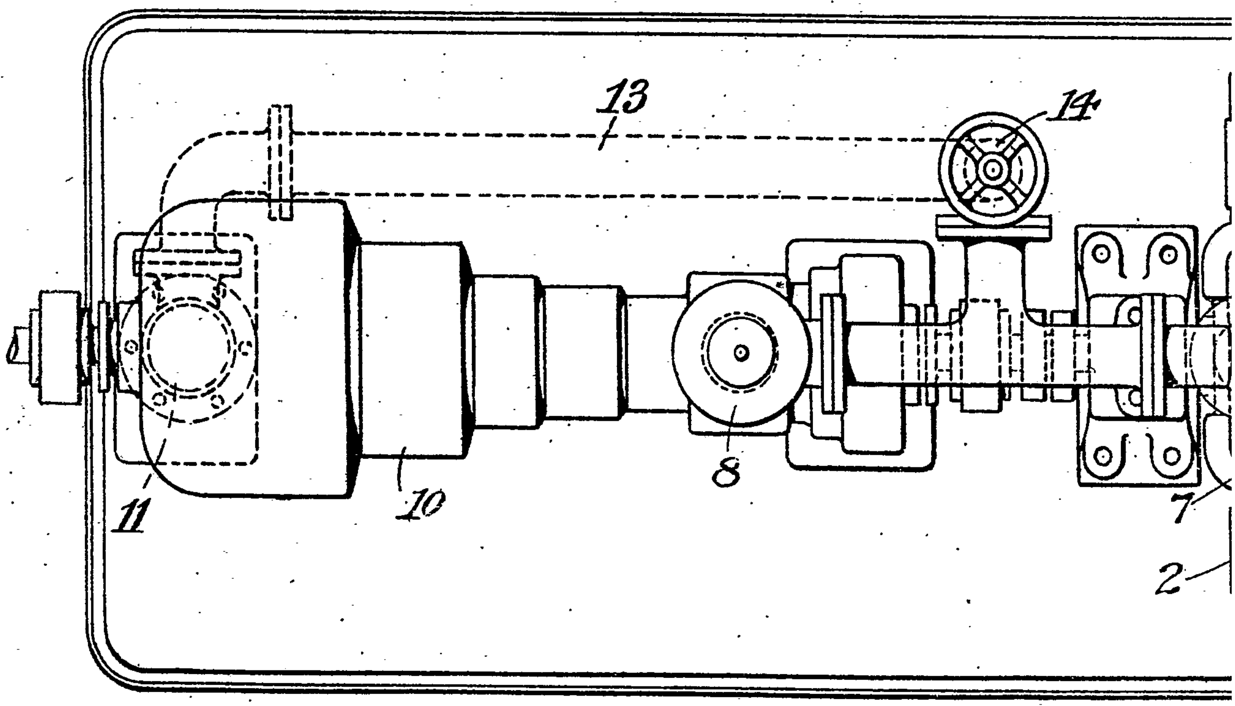
Hereford: Printed for His Majesty's Stationery Office, by The Hereford Times Ltd.
[Wt. 70—125/10/1923.]

2nd Edition

[This Drawing is a full-size reproduction of the Original.]

Fig. 1





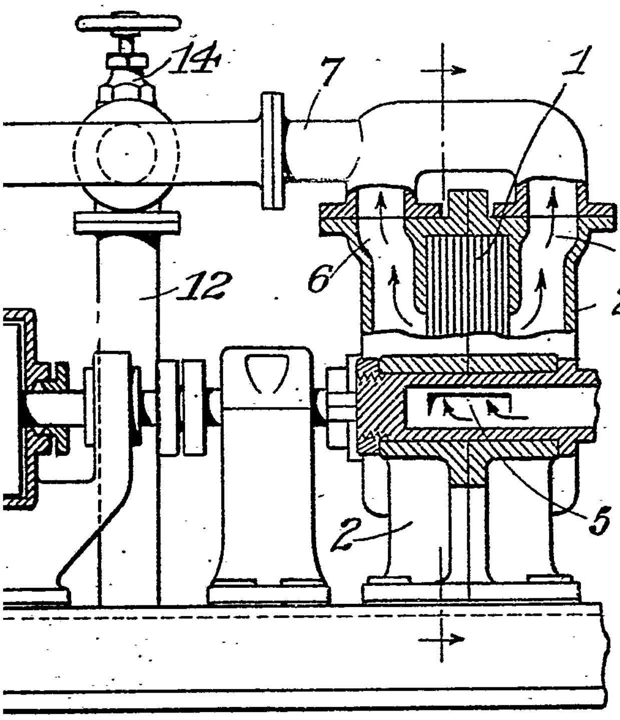


Fig. 3

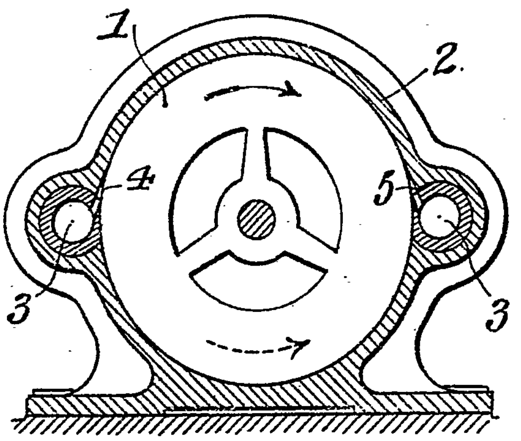
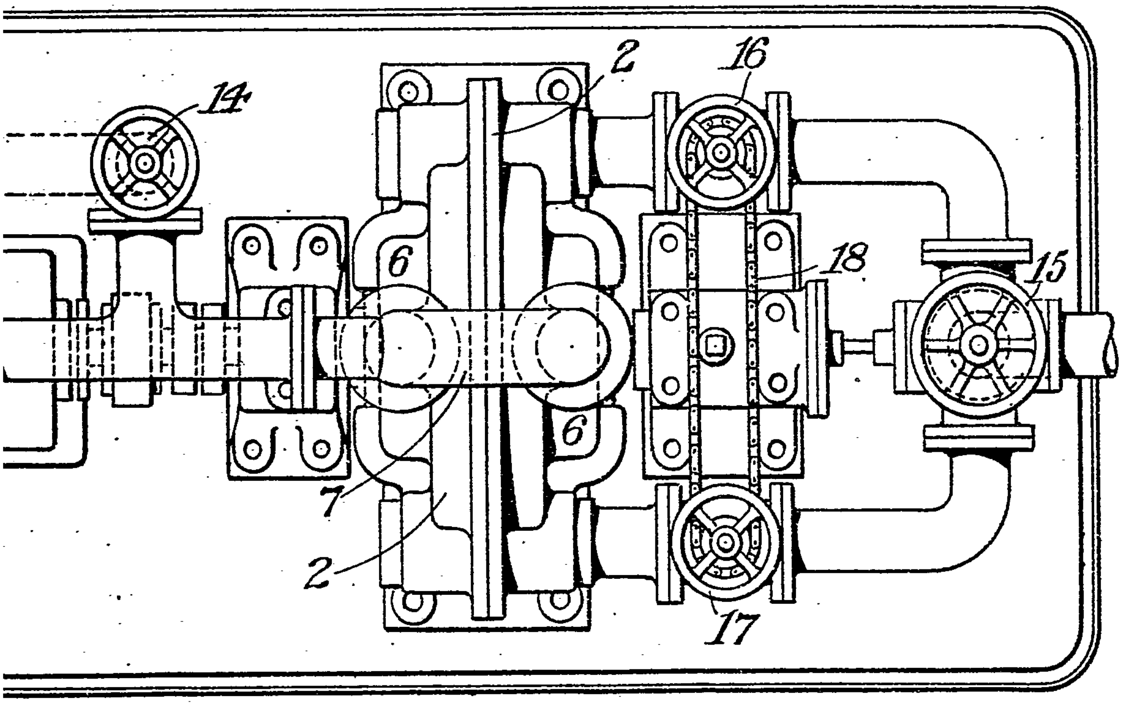


Fig. 2



2nd Edition

Fig. 1

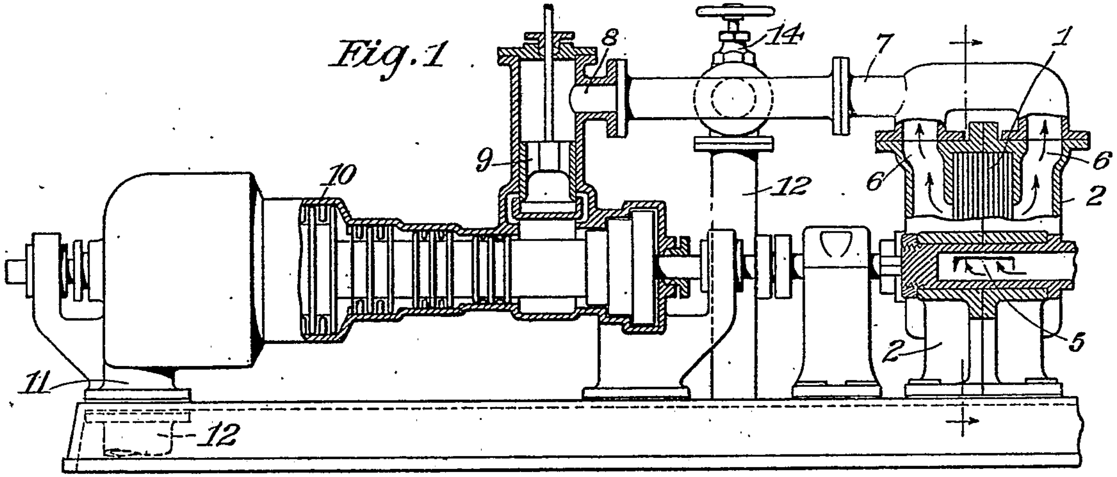


Fig. 3

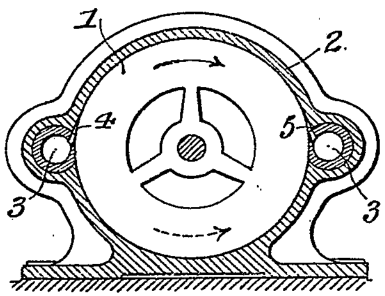
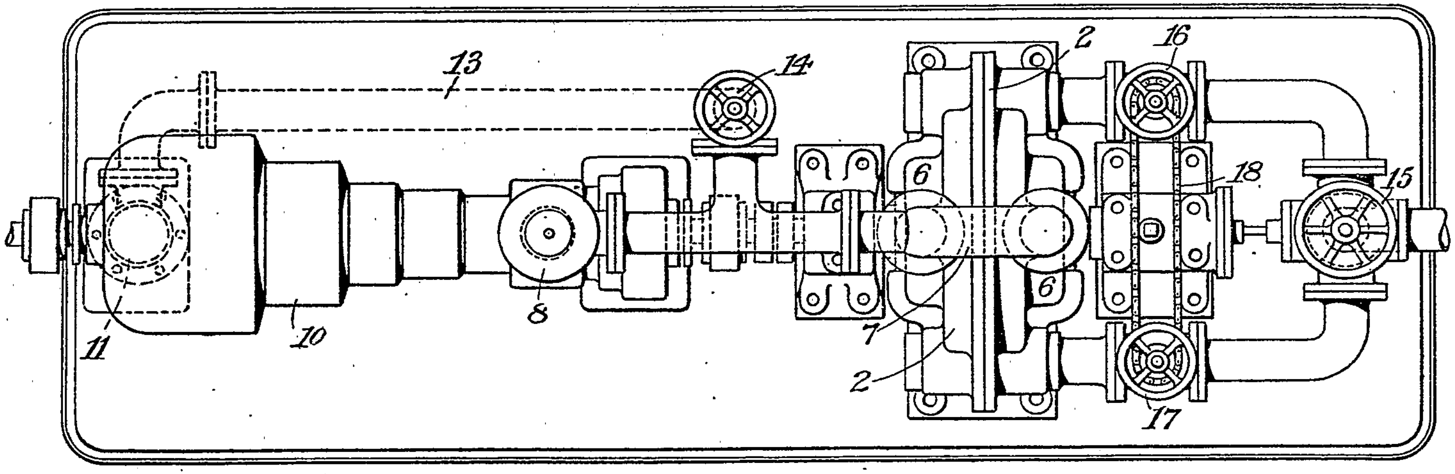


Fig. 2



[This Drawing is a full-size reproduction of the Original.]

Malby&Sons, Photo-Litho

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PATENT SPECIFICATION

179,043

Application Date: Mar. 24, 1921. No. 9098/21.
Complete Left: Sept. 5, 1921.
Complete Accepted: May 4, 1922.

PROVISIONAL SPECIFICATION.

Improved Process of and Apparatus for Production of High Vacua.

I, Nikola Tesla, Mechanical and Electrical Engineer, citizen of the United States of America, of 8, West 40th Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

In the development of power by thermodynamic primemovers, as steam engines and turbines, a low back pressure is essential to good economy, the performance of the machine being increased from fifty to one hundred *per cent.* by reducing the absolute pressure in the exhaust space from fifteen to about one pound per square inch. Turbines are particularly susceptible to such improvement and in their use for operation of power plants and manufacturing establishments the attainment and steady maintenance of high vacua has assumed great importance, every effort being made to better the conditions in this respect. The gain effected by this means is, in a large measure, dependent on the initial pressure, characteristics of the primemover, temperature of the cooling medium, cost of the condensing apparatus and many other things which are all well-known to experts. The theoretical saving of from five to six *per cent.* of fuel for each additional inch of vacuum is often closely approximated in modern installations, but the economic advantages are appreciably lessened when higher vacua are applied to existing machines purposely designed to operate with lower ones. More especially is this true of a turbine in which the reduction of back pressure merely increases the velocity of exit of the vapors without materially augmenting the speed of their impact against the vanes, buckets, or equivalent organs, when the loss of kinetic energy in the exhaust may offset a considerable portion of the useful work. In such cases some constructional changes in the turbine and auxiliaries may have to be made in order to secure the results here contemplated but the additional capital used for this purpose will be profitably invested. Summing up the situation it may be generally stated that a more or less substantial reduction of fuel cost can be made in most of the existing power plants by the adoption of proper pumping apparatus and establishment of working conditions nearly corresponding to those of an ideal condenser.

The chief difficulties which have thus far retarded advancement in this direction are encountered in the enormous volumes of the air and vapor at very low pressures as well as unavoidable leaks in the condenser, pipe joints, valves, glands and stuffing boxes. At present exhaustion is usually accomplished by reciprocating pumps and these, on account of the necessarily low speed of the pistons are large and, moreover, incapable of satisfactory performance in the presence of big leaks. As a direct result of this the condensing plant is both bulky and expensive and, worse still, its size and cost increase entirely in disproportion to the results attained. To illustrate—the outlay involved in the instalment of condensing apparatus for a twenty-eight inch vacuum is more than double that required for a vacuum of twenty-six inches and these draw-backs are still more emphasized with the further reduction of the back pressure. Rotary pumps and jets of water and steam are also used in the production of vacua, but without marked qualitative advantages. As to the possible employment of multi-stage centrifugal exhausters, engineers are still in doubt. Such machines have heretofore served only for purposes of compression and it is more than probable that they would prove unsuitable for very high rarefaction. The introduction of Sir Charles Parsons' "vacuum augmentor" and Weir's "dry air" pump was a decided progress towards the desired goal, nevertheless this important problem has only been partially solved and to this day the condensing apparatus is admittedly the most troublesome part of the whole power mechanism, to such an extent, indeed, that its duplication is often deemed advisable if not absolutely necessary to the safe and reliable working of the plant.

I have achieved better success in departing from the customary method of removing the air and entrained steam from the condenser by bodily carriers as jets, reciprocating pistons or rotating vanes, and availing myself of the properties of adhesion and viscosity which, according to experimental evidence, are retained by the gases and vapors even at very high degrees of attenuation. The new process which I have thus evolved is rendered practicable through a novel type of pump which I have invented and described in my British Patent No. 24,001 of 1910. This device, suitably modified in certain details of construction and run at the excessive peripheral speed of which an unloaded system is capable, exhibits two remarkable and valuable properties. One of these is to expel the rarefied fluids at such an immense rate that a hole of some size can be drilled in the condenser without much effect on the vacuum gauge. The other is to draw out the fluids until the exhaustion is almost complete. A machine of this kind, constructed in stages, is alone sufficient for the production of extremely high vacua and I believe this quality to be very valuable inasmuch as it is not possessed to such a degree by other types of commercial pumps which have come to my knowledge. However, in order to avoid undue complication and expense I make use of the ordinary exhausting apparatus and simply insert between it and the condenser my pump, which sucks out the highly attenuated media, compresses and delivers them to the "dry air" or other pump. This combination is especially advantageous from the practical point of view as good results can be secured with a single stage and the instalment of my device calls for but a slight change in the steam plant. The benefits derived are twofold: a higher vacuum is attained and, what is perhaps more important, the frequent and unavoidable impairments of the same, which seriously affect the economy, are virtually eliminated. My pump makes possible the maintenance of high vacua even when the percentage of air or other fluids carried with the steam is very great and on this account should prove particularly useful in the operation of mixed fluid turbines.

Dated this 24th day of March, 1921.

NIKOLA TESLA.

COMPLETE SPECIFICATION.

Improved Process of and Apparatus for Production of High Vacua.

I, Nikola Tesla, Electrical and Mechanical Engineer, citizen of United States of America, of No. 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In the development of power by thermodynamic primemovers, as steam engines and turbines, a low back pressure is essential to good economy, the performance of the machine being increased from fifty to one hundred *per cent.* by reducing the absolute pressure in the exhaust space from fifteen to about one pound per square inch. Turbines are particularly susceptible to such improvement and in their use for operation of power plants and manufacturing establishments the attainment and steady maintenance of high vacua has assumed great importance, every effort being made to better the conditions in this respect. The gain effected by this means is, in a large measure, dependent on the initial pressure, characteristics of the primemover, temperature of the cooling medium, cost of the condensing apparatus and many other things which are all well-known to experts. The theoretical saving of from five to six *per cent.* of fuel for each additional inch of vacuum is often closely approximated in modern installations, but the economic advantages are appreciably lessened when higher vacua are applied to existing machines purposely designed to operate with lower ones. More especially is this true of a turbine in which the reduction of back pressure merely increases the velocity of exit of the vapors without materially augmenting the speed of their impact against the vanes, buckets, or equivalent organs, when the loss of kinetic energy in the exhaust may offset a considerable portion of the useful work. In such cases some constructional changes in the turbine and auxiliaries may have to be made in order to secure the results here contemplated but the additional capital used for this purpose will be profitably invested. Summing up the situation it may be generally stated that a more or less substantial reduction of fuel cost can be made in most of the existing power plants by the adoption of proper pumping apparatus and establishment of working conditions nearly corresponding to those of an ideal condenser.

The chief difficulties which have thus far retarded advancement in this direction are encountered in the enormous volumes of the air and vapor at very low pressures as well as unavoidable leaks in the condenser, pipe joints, valves, glands and stuffing boxes. At present exhaustion is usually accomplished by reciprocating pumps and these, on account of the necessarily low speed of the pistons are large and, moreover, incapable of satisfactory performance in the presence of big leaks. As a direct result of this the condensing plant is both bulky and expensive and, worse still, its size and cost increase entirely in disproportion to the results attained. To illustrate—the outlay involved in the instalment of condensing apparatus for a twenty-eight inch vacuum is more than double that required for a vacuum of twenty-six inches and these draw-backs are still more emphasized with the further reduction of the back pressure. Rotary pumps and jets of water and steam are also used in the production of vacua, but without marked qualitative advantages.

I have achieved better success in departing from the customary method of removing the air and entrained steam from the condenser by bodily carriers as jets, reciprocating pistons or rotating vanes, and availing myself of the properties of adhesion and viscosity which, according to experimental evidence are retained by the gases and vapors even at very high degrees of attenuation. This new process is rendered practicable through a pump, the underlying principle of which is fully explained in my British Patent 24,001 of 1910, but which is modified as hereinafter described and when run at the very great peripheral speed of which an unloaded system is capable, exhibits two remarkable and valuable properties. One of these is to expel the rarefied fluids at such an immense rate that a hole of some size can be drilled in the condenser without much effect on the vacuum gauge. The other is to draw out the fluids until the exhaustion is almost complete. A machine of this kind, constructed in stages, is alone sufficient for the production of extremely high vacua and I believe this quality to be very valuable inasmuch as it is not possessed to such a degree by other types of commercial pumps which have come to my knowledge. I have also found that a very effective combination is produced by inserting my pump between the condenser and a " dry air " or other pump. This combination is especially advantageous from the practical point of view as good results can be secured with a single stage and the instalment of my device calls for but a slight change in the steam plant. The benefits derived are twofold; a higher vacuum is attained and, what is perhaps more important, the frequent and unavoidable impairments of the same, which seriously affect the economy, are virtually eliminated. My pump makes possible the maintenance of high vacua even when the percentage of air or other fluids carried with the steam is very great and on this account should prove particularly useful in the operation of mixed fluid turbines.

My invention will be more fully understood by reference to the accompanying drawings in which Fig. 1 shows a multistage pump of this kind in sectional views, and Fig. 2 illustrates its use in connection with a double-acting reciprocating pump.

In the first figure, 1, 2, . . . are rotors each of which, as 1, comprises a number of relatively thin disks 3, 3 . . . separated by starwashers 4, 4 . . . and held together by rigid end-plates 5 and 6 on a sleeve 7 which is fitted and keyed to a shaft 8, rotatably supported in bearings 9, 9. The rotors are contained in separate chambers of a common structure 10 which surrounds them and is made up of parts held together by flange connections. Beginning with the fist stage at 1, the rotors diminish in width, each following being made narrower than the preceding, for obvious economic reasons. All the thin discs, as 3, 3 . . . , and lefthand end-plates, as 5, are provided with the usual central openings, but the righthand end-plates, as 6, are blank. The individual chambers, containing the rotors, communicate with each other through channels, as 11, extending from the peripheral region of one to the central part of the next, so that the fluids aspired at the intakes 12, 12 are compelled to pass through the whole series of rotors and are finally ejected at the flanged opening 13 of the last chamber. In order to reduce leakage along the shaft, close-fitting joints or locks, as 14, are employed which may be of ordinary construction and need not be dwelled upon specifically. The number of stages will depend on the peripheral velocity and the degree of exhaustion which it is desired to secure, and in extreme cases a number of separate structures, with intermediate bearings for the shaft, may have to be provided. When found preferable the pump may be of the double-flow type, when there will be no appreciable side thrust, otherwise provision for taking it up shoulde be made.

The modifications in details of construction, to which reference has been made, consist in the employment of smaller spaces between the discs than has hitherto been the case, and of close side-clearances. To give a practical example, I may state that spaces of $^{3}/_{64}$ of an inch will be effective in the production of very high vacua with discs of, say, 24 inches in diameter. I also make all discs tapering, when necessary, in order to operate safely at an extremely high peripheral velocity which is very desirable since it reflects both on the size of the machine and its effectiveness.

The arrangement represented diagrammatically in Fig. 2 is especially suitable and advantageous in connection with existing steam plants operating with high vacuum and permits the carrying out of my improvements in a simple manner and at comparatively small cost. In this case my pump, which may have but one rotor of the above description, is connected with its intake 12, through a pipe 15, to the top of a condenser 16, and with its discharge opening 13, by pipe 17, to the suction duct of a reciprocating dry air pump 18. It goes without saying that in actual practice connections 15 and 17 will be short mains of very large section as the volume of fluids to be pumped may be enormous.

The operation will be readily understood from the foregoing. The intakes 12 (Fig. 1) being joined by an air-tight connection to the vessel to be exhausted and the system of discs run at very high peripheral velocity the fluids, by reason of their properties of viscosity and adhesion, are drawn out of the vessel until the degree of rarefaction is attained for which the apparatus has been designed. In their passage through the series of rotors the fluids are compressed by stages and ejected through the opening 13 at a volume greatly reduced. The vacuum produced by this means may be extremely high because of the apparently unique properties of the device pointed out before, and as the fluids, irrespective of their density, are sucked out at an excessive speed, leaks through the glands, stuffing boxes and connections are of but slight effect.

In the arrangement shown in Fig. 2 my pump serves to evacuate the condenser much more effectively and by compressing the fluids at the intake of the reciprocating pump improves the performance of the same. The instalment of the device in existing plants does not call for extensive alterations in the same and will result in a notable saving of fuel. My pump may also be advantageously employed in place of a steam jet in conjunction with a small condenser in which case it will be of insignificant dimensions and economical in steam consumption.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The improved process of rarefaction which consists in rotating a disc system communicating with a receptacle and continuously ejecting fluid adhering to said system, until a high vacuum is attained in the receptacle, as described.

2. The improved method of exhausting a vessel which consists in rotating a system of discs and continuously applying the frictional force, arising from the

viscosity of the fluid and its adhesion to said system, to exhaust the vessel until a high vacuum is attained, substantially as described.

3. The improved process of rarefaction which consists in sucking out of a vessel attenuated fluids by the frictional force of a system of rotating discs, compressing them in the passage through the same, and discharging them into the intake duct of a positively acting pump, as described.

4. As a means for obtaining high vacua, the combination of apparatus, as illustrated and described.

Dated the 23rd day of August, 1921.

NIKOLA TESLA.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1922.

[This Drawing is a reproduction of the Original on a reduced scale]

Fig.1

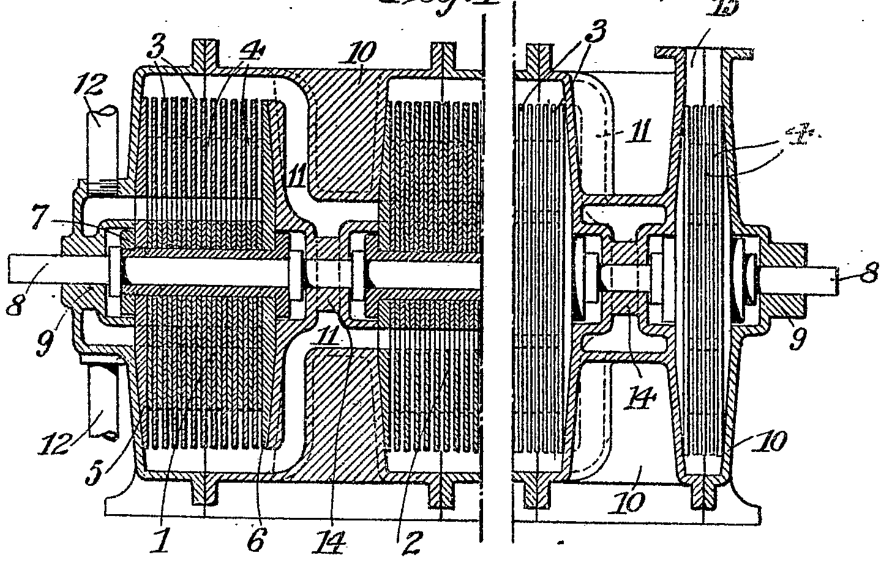
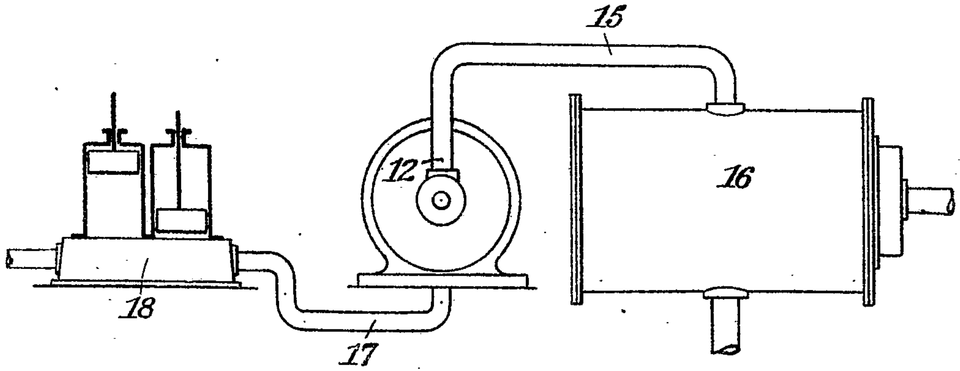


Fig. 2



Malby & Sons, Photo-Litho

PATENT SPECIFICATION

Application Date: Apr. 4, 1921. No. 9961/21. **185,446**

Complete Left: Sept. 5, 1921.

Complete Accepted: Sept. 4, 1922.

PROVISIONAL SPECIFICATION.

Method of and Apparatus for Aerial Transportation.

I, Nikola Tesla, Mechanical and Electrical Engineer, citizen of the United States of America, of 8, West 40 Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

The utility of the aeroplane as a means of transport is materially lessened and its commercial introduction greatly hampered owing to the inherent inability of the mechanism to readily rise and alight, which is an unavoidable consequence of the fact that the required lifting force can only be produced by a more or less rapid translatory movement of the planes or foils. In actual experience the minimum speed for ascension and landing is a considerable fraction of that in full flight, and the principles of design do not admit of a very great advance in this respect without sacrifice of some desirable features. For this reason planes of very large area, high lift wing-sections, deflectors of the slipstream of the propeller, or analogous means, which might be helpful in these operations, do not afford the remedy sought. This indispensable high velocity, imperilling life and property, makes it necessary to equip the machine with special appliances and provide suitable facilities at the terminals of the route, all of which entail numerous drawbacks and difficulties of a serious nature. So imperative has it become to discover some way of doing away with these limitations of the aeroplane that the consensus of expert opinion characterizes the problem as one of the most pressing and important and its practical solution is eagerly awaited by those engaged in the development of the art, as well as the general public.

[*Price* 1/-]

Many attempts have been made to this end, mostly based on the use of independent devices for the express purpose of facilitating and insuring the start and finish of the aerial journey, but the operativeness of the arrangements proposed is not conclusively demonstrated and, besides, they are objectionable, constructively or otherwise, to such an extent that builders of commercial apparatus have so far not considered them of sufficient value to depart from present practice.

More recently, professional attention has been turned to the helicopter which is devoid of planes as distinct organs of support and, presumably, enables both vertical and horizontal propulsion to be satisfactorily accomplished through the instrumentality of the propeller alone. However, although this idea is quite old and not a few experts have endeavored to carry it out in various ways, no success has as yet been achieved. Evidently, this is due to the inadequacy of the engines employed and, perhaps, also to certain heretofore unsuspected characteristics of the device and fallacies in the accepted theory of its operation, an elucidation of which is deemed necessary for the clear understanding of the subject.

The prospects of a flying machine of this kind appear at first attractive, primarily because it makes possible the carrying of great loads with a relatively small expenditure of energy. This follows directly from the fundamental laws of fluid propulsion, laid down by W. T. M. Rankine more than fifty years ago, in conformity with which the thrust is equal to the integral sum of the products of the masses and velocities of the projected air particles; symbolically expressed,

$$T = \sum (mv).$$

On the other hand, the kinetic energy of the air set in motion is

$$E = \sum (\tfrac{1}{2}mv^2).$$

From these equations it is evident that a great thrust can be obtained with a comparatively small amount of power simply by increasing the aggregate mass of the particles and reducing their velocities. Taking a special case for illustration, if the thrust under given conditions be ten pounds per horsepower, then a hundredfold increase of the mass of air, accompanied by a reduction of its effective velocity to one-tenth, would produce a force of one hundred pounds per horsepower. But the seemingly great gain thus secured is of little significance in aviation, for the reason that a high speed of travel is generally an essential requirement which can not be fulfilled except by propelling the air at high velocity, and that obviously implies a relatively small thrust.

Another quality commonly attributed to the helicopter is great stability, this being, apparently, a logical inference judging from the location of the centers of gravity and pressure. It will be found, though, that contrary to this prevailing opinion the device, while moving in any direction other than up or down, is in an equilibrium easily disturbed and has, moreover, a pronounced tendency to oscillate. It is true, of course, that when the axis of the propeller is vertical and the ambient air quiscent the machine is stable to a degree, but if it is tilted even slightly, or if the medium becomes agitated, such is no longer the case.

In explanation of this and other pecularities, assume the helicopter poised in still air at a certain height, the axial thrust T just equalling the weight, and let the axis of the propeller be inclined to form an angle α with the horizontal. The change to the new position will have a twofold effect: the vertical thrust will be diminished to

$$T_v = T \sin \alpha,$$

and at the same time there will be produced a horizontal thrust

$$T_h = T \cos \alpha.$$

Under the action of the unbalanced force of gravity the machine will now fall along a curve to a level below and if the inclination of the propeller as well as its speed of rotation remain unaltered during the descent, the forces T, T_v and T_h will continuously increase in proportion to the density of the air until the vertical component T_v of the axial thrust T becomes equal to the gravitational attraction. The extent of the drop will be governed by the inclination of the propeller axis and for a given angle it will be, theoretically, the same no matter at what altitude the events take place. To get an idea of its magnitude suppose the elevations of the upper and low strata measured from sea level be h_1 and h_2, respectively, d_1 and d_2 the corresponding air densities and H=26,700 feet the height of the "uniform atmosphere", then as a consequence of Boyle's law the relation will exist

$$h_1 - h_2 = H \log_e \frac{d_2}{d_1}$$

It is evident that

$\frac{T}{T_v} = \frac{T}{T \sin \alpha} = \frac{1}{\sin \alpha} = \frac{d_2}{d_1}$ in order that the vertical component of the axial thrust in the lower stratum should just equal the weight. Hence

$$h_1 - h_2 = H \log_e \frac{1}{\sin \alpha}.$$

Taking, in a special case, the angle $\alpha = 60^\circ$, $\frac{1}{\sin \alpha} = \frac{1}{0.866} = 1.1547$ and

$h_1 - h_2 = 26{,}700 \times \log_e 1.1547 = 3840$ feet.

In reality, the drop will be much greater for the machine, upon reaching the lower layer with a high velocity relative to the medium will be urged further along the path and the kinetic energy, in the vertical sense, possessed by the moving mass must be annihilated before the fall is arrested in a still denser air stratum. At this point the upward thrust will be far in excess of the opposed pull of the weight and the apparatus will rise with first increasing and then diminishing speed to nearly the original height. From there it will again fall and so on, these operations being repeated during the forward flight, the excursions gradually diminishing in magnitude. After a lapse of time, determined by numerous influences, the oscillations should cease altogether and the path described become rectilinear. But this is next to impossible as can be readily shown by pointing out another curious feature of the helicopter.

In the foregoing the axis of the propeller was supposed to move always parallel to itself, which result might be accomplished by the use of an adjustable aileron. In this connection it may be pointed out that such a device will not act in the manner of a rudder, coming into full play at intervals only and performing its functions economically, but will steadily absorb energy, thus occasioning a considerable waste of motive power and adding another to the many disadvantages of the helicopter.

Let now the machine be possessed of a certain degree of freedom, as will be the case normally, and observe in the first place that the blades of the propeller themselves constitute planes developing a reaction thrust, the pressure on the lower leading blade being greater than that exerted on the higher one owing to the compression of the air by the body of the machine and increased density in that region. This thrust, tending to diminish the angle a, will obviously vary during one revolution, being maximum in a position when the line of symmetry of the two propeller blades and that of flight are in a vertical plane and minimum at right angles to it; nevertheless, when the horizontal speed is great it may be considerable and sufficient to quickly overcome the inertia and gyroscopic resistances. Moreover, this disturbing effect partakes of the regenerative quality, the force increasing as the angle a diminishes up to a maximum for $a=45°$. As the axis is tilted more and more, the vertical sustaining effort of the propeller will correspondingly diminish and the machine will fall with a rapidly increasing velocity, finally exceeding the horizontal when the reaction of the blades will be directed upward so as to increase the angle a and thereby cause the machine to soar higher. Thus periodic oscillations, accompanied by ascents and descents, will be set up which may well be magnified to an extent such as to bring about a complete overturn and plunge to earth.

It is held by some experts that the helicopter, because of its smaller body resistance, would be capable of a higher speed than the aeroplane. But this is an erroneous conclusion, contrary to the laws of propulsion. It must be borne in mind that in the former type, the motive power being the same, a greater mass of air must be set in motion with a velocity smaller than in the latter, consequently it must be inferior in speed. But even if the air were propelled in the direction of the axis of the screw with the same speed V in both of them, while the aeroplane can approximate the same, the helicopter could never exceed the horizontal component $V \cos a$ which, under the theoretically most economical conditions of operation, would only be 0.7V.

Another very serious defect of this kind of flying machine, from the practical point of view, is found in the inability of supporting itself in the air in case of failure of the motor, the projected area of the propeller blades being inadequate, for reducing the speed of the fall sufficiently to avoid disaster, and this is a fatal impediment to its commercial use.

From the preceding facts, which are ignored in the technical publications on the subject, it will be clear that the successful solution of the problem is in a different direction.

My invention meets the present necessity in a simple manner without radical departures in construction and sacrifice of valuable features, incidentally securing advantages which should prove very beneficial in the further development of the art. Broadly expressed, it consists in a novel method of transporting bodies through the air in which the machine is raised and lowered solely by the propeller and sustained in its flight by planes. The chief innovations in the mechanism are a prime mover of the kind described in my British Patent No. 24,001 of 1910, a specially designed propeller and arrangements whereby the machine is automatically, or through wilful control, transformed from the helicopter into an aeroplane and *vice versa*.

In the preferred form of design the structure is composed of two planes or foils rigidly joined, their length and distance apart being such as to form a square for the sake of smallness and compactness. With the same object the tail is omitted or, if used, it is retractable. The turbine and other parts of the motive apparatus are placed as in an aeroplane and also the usual controls are provided. At rest the planes are vertical or nearly so and likewise the propeller which is relatively large and built for great strength in order to support safely the entire weight. The seat of the aviator and passengers is suspended on trunnions on which it can turn through an angle of about 90°, springs and cushions being employed to insure and limit its motion through this angle. Hand- and foot-controlled devices are placed so as to be within easy reach of the driver in any position.

At the start, power being turned on, the machine rises vertically in the air to the desired height when it is gradually tilted and becomes an aeroplane, the foils taking up the load as the speed in the horizontal direction increases. In descending, the forward speed is reduced and the machine righted again, becoming a helicopter with the propeller supporting all the load. The turbine referred to is a motor of exceptional lightness and activity and lends itself to this kind of use for which ordinary aviation motors are unsuited. It is capable of carrying a great overload and running without danger at excessive speed so that in the starting and landing operations the necessary power can be developed, even though less efficiently than under normal conditions. However, should the propelling mechanism fail, landing can still be effected without much risk in the usual manner. Such a helicopter-plane constructed as indicated and operated in the manner described, unites the advantages of both types and seems to meet best the requirements of a small, compact, exceedingly speedy and yet very safe machine for commercial use.

Dated this 31st day of March, 1921.

NIKOLA TESLA.

COMPLETE SPECIFICATION.

Method of and Apparatus for Aerial Transportation.

I, Nikola Tesla, Electrical and Mechanical Engineer, citizen of the United States of America, of 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to aerial machines of the kind in which the machine is adapted to be raised and lowered in the manner of a helicopter with the chords of the planes and the axis of the propelling means vertical and in which the planes and propelling means are adapted to be turned through a right angle in the air so that the chords of the planes and the axis of the propelling means are more or less horizontal and the machine can be flown as an aeroplane.

The utility of the aeroplane as a means of transport is materially lessened and its commercial introduction greatly hampered owing to the inherent inability of the mechanism to readily rise and alight, which is an unavoidable consequence of the fact that the required lifting force can only be produced by a more or less rapid translatory movement of the planes or foils. In actual experience the minimum speed for ascension and landing is a considerable fraction of that in full flight, and the principles of design do not admit of a very great advance in this respect without sacrifice of some desirable feature.

More recently professional attention has been turned to the helicopter, which is devoid of planes as distinct organs of support, and, presumably, enables both vertical and horizontal propulsion to be satisfactorily accomplished through the instrumentality of the propeller alone. However, although the idea is quite old and not a few experts have endeavored to carry it out in various ways, no practical success has yet been achieved.

A very serious defect of this kind of flying machine, from the practical point of view, is found in its inability of supporting itself in the air in case of failure of the motor, the projected area of the propeller blades being inadequate for reducing the speed of the fall sufficiently to avoid disaster, and this is an almost fatal impediment to its commercial use.

The type of machine to which this invention relates enables many of these disadvantages to be avoided but in order to obtain practical success I have found that provision must be made for the very different burdens which investigation shows fall upon the engine when the machine is being raised vertically and when it is being propelled horizontally and that to accomplish this an engine must be employed which is capable of standing a considerable over-load during the period of vertical ascent and of rotating at greatly increased speed during this time compared with the speed to be normally used during horizontal flight.

One of the features of this invention is the construction of an aeroplane of the above-named type actuated by an engine adapted to run at such over-load and for this purpose I use a prime-mover of the kind described in my British Patent No. 24,001 of 1910.

Another feature is that the machine is so constructed that it can start or descend either vertically as an helicopter or at an angle as an aeroplane and for this purpose two landing bases approximately at right angles to one another are provided.

Other subsidiary features of the invention are set out in the description following.

Full knowledge of these improvements will be readily gained by reference to the accompanying drawings in which Fig. 1 illustrates the machine in the starting or landing position and Fig. 2, in horizontal flight. Fig. 3 is a plan view of the same with the upper plane partly broken away.

The structure is composed of two planes or foils 1, 1, rigidly joined, the chord and gap of which may be nearly equal. The tail is omitted or, if used, it should be retractable. The motors 2, 2, in this case turbines of the kind described in my patent before referred to, and other parts of the motive apparatus are placed with due regard to the centres of gravity and pressure and the usual controlling means are provided. In addition to these any of the known stabilizing devices may be embodied in the machine. At rest the planes are vertical, or nearly so, and likewise the shaft driving the propeller 3, which is constructed of a strength, size and pitch that will enable it to raise the entire weight with the motor running at an even greater rate than when propelling the machine horizontally. Power is transmitted to the shaft from the turbines through suitable gears. The seats 4, 4, 4, for the operator and passengers are suspended on trunnions 5, 5 on which they may turn through an angle of about 90°, springs and cushions (not shown) being employed to insure and limit their motion through this angle. The usual devices for lateral and directional control, 6, 6, 7, 7 and 8, 8 are provided with mechanical connections enabling the operator to actuate the devices by hand or foot from his seat in any position. At the start, sufficient power being turned on by suitable means, also within his reach, the machine rises vertically in the air to the desired height when it is gradually tilted by manipulating the elevator devices and proceeds like on aeroplane, the load being transferred from the propeller to the foils as the angle of inclination diminishes and the speed in horizontal direction increases. In descending the forward speed may be reduced and the machine righted again, acting as a helicopter with the propeller supporting all the load. The type of turbine which, as stated above, I prefer is a motor of great lightness and activity and lends itself exceptionally to this kind of work for which ordinary aviation motors are unsuited. It is capable of carrying a great overload and running without danger at excessive speed so that during the starting and landing operations the necessary power can be developed by the motors even though less efficiently than under their normal working conditions. Special means of control may be provided, if necessary, for increasing the power supply in these operations. Owing to its extreme simplicity the motive apparatus is very reliable in operation. Ascent and descent can be effected either with the planes vertical or in the manner of aeroplanes of the usual type. For this purpose, in addition to wheels 9, 9 and 10, 10, wheels 11, 11 are employed, the latter being mounted on the forward end under the lower plane so that when the machine rests on level ground the propeller shaft will have the desired inclination which is deemed best for rising in the manner of an aeroplane. Such a helicopter-plane constructed and operated as described, unites the advantages of both types and seems to meet best the requirements of a small, compact, exceedingly speedy and yet very safe machine for commercial use.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is:—

1. A flying machine capable of vertical movement under the influence of its propeller or propellers and also of movement in the manner of an aeroplane actuated by a motor or motors so constructed that it or they are adapted to rotate its propeller or propellers at a speed greatly exceeding normal when rising or descending vertically while such speed can be reduced to the normal when it is flying horizontally and supported by its planes.

2. Flying machine as described and claimed in Claim 1 of which the motor or motors are of the type described in British Specification No. 24,001 of 1910.

3. Flying machine as described and claimed in the preceding claims actuated by a single propeller which when it is ascending vertically is above the centre of gravity of the machine.

4. A flying machine so constructed that it can start and descend either straight up and down like a helicopter or at an angle like an aeroplane and can be tilted as a whole in the air from its

vertical to its horizontal position and *vice versa*, substantially as described.

5. Flying machine as described and claimed in Claim 4 provided with two wheel bases substantially at right angles.

6. Flying machine as described and claimed in the preceding claim in which one or more wheels are common to the two bases.

7. Flying machine constructed substantially as described and shown in the drawings.

Dated this 25th day of August, 1922.

NIKOLA TESLA,
By James R. Hatmaker,
His Attorney.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1922.

[*This Drawing is a reproduction of the Original on a reduced scale*]

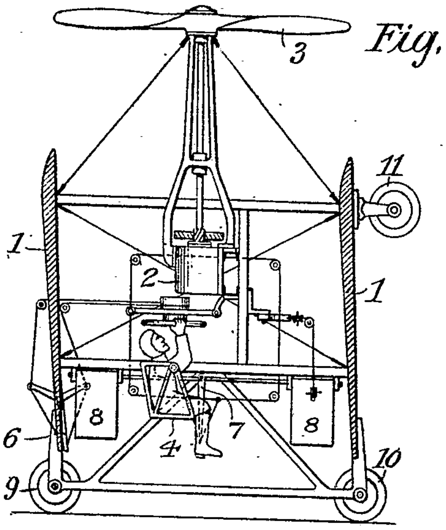


Fig. 1

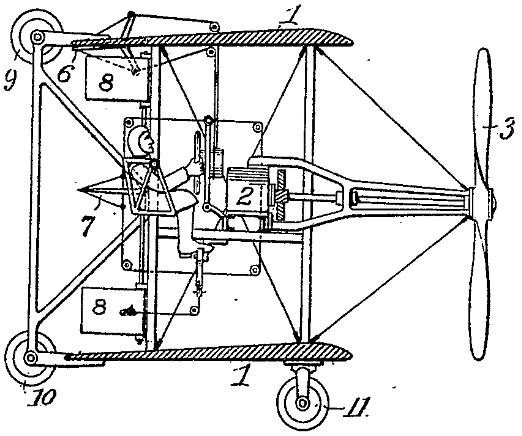


Fig. 2

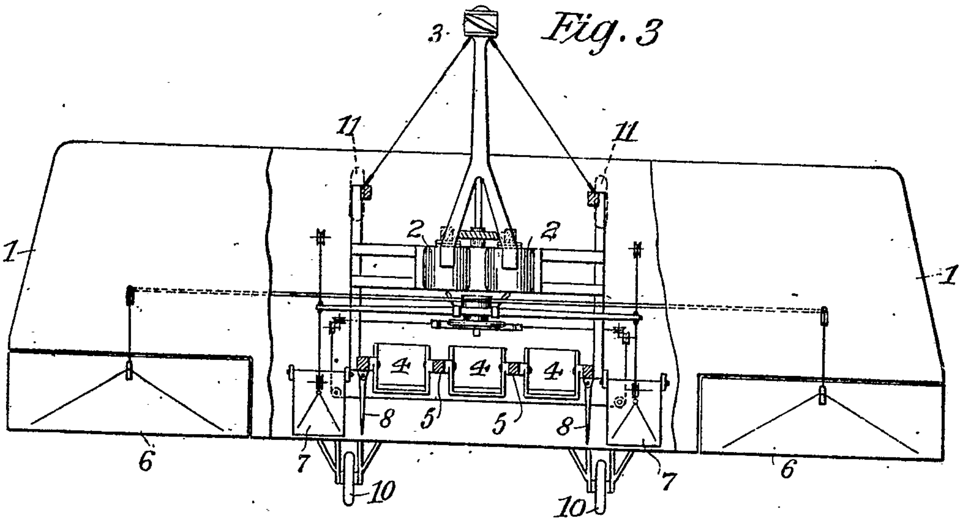


Fig. 3

RESERVE COPY

PATENT SPECIFICATION

Application Date: Mar. 24, 1921. No. 9097/21.

Complete Left: Sept. 2, 1921.

Complete Accepted: Sept. 25, 1922.

186,082

PROVISIONAL SPECIFICATION.

Improvements in the Construction of Steam and Gas Turbines.

I, Nikola Tesla, Mechanical and Electrical Engineer, citizen of the United States of America, of 8, West 40th Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

In a British Patent, Number 24,001 of 1910, I have described a bladeless turbine having a rotor consisting of discs with openings in the central portions and separating star-washers, these parts when assembled being riveted together into a single solid structure and keyed to the shaft. This form of rotor operates satisfactorily but in long experience certain improvements in its construction have been found desirable and these constitute my present invention.

In the new design I employ two heavier end-plates which are machined tapering toward the periphery for the purpose of reducing the maximum centrifugal stress as much as practicable. The inside discs, of relatively thin material, are rolled, forged or ground tapering in like manner and with the same object in view, but this may not always be necessary and plates, made of sheet metal of substantially uniform thickness as furnished by the mills, can be employed. Each of the thick as well as thin plates is provided with exhaust openings, leaving a solid central portion like the hub and spokes of a wheel. Star-washers of similar configuration serve the purpose of keeping the discs apart in the center and for the peripheral spacing the thin plates have small holes drilled in them on a circle, or circles, of suitable diameter, and in these are driven tight-fitting studs which are upset at both ends by a special tool so that they will project beyond the metal on each side a trifle more than the thickness of the star-washers. When the plates are put together the separating studs do not come in line but are straddled in order to give opportunity for slight yielding, thereby eliminating constructional difficulties which might be caused by unevenness or other mechanical imperfections. Thus the rotor can be finished closely to predetermined overall dimensions and will run true on the outside even if the thin inside plates should vary a little in thickness or be slightly warped. To simplify this arrangement I provide only every second plate with studs, using plain ones between. Furthermore, with the object of cheapening the manufacture I dispense altogether with the former, accomplishing the spacing by means of small bosses or protuberances which are raised in the plates by blows or pressure and provide a die, practically reducing all the machine work on a thin plate to a single operation in a stamping press. The star-washers, while preferable, are not indispensable and may be replaced by round separating washers of a diameter about equal to that of the hub part of the discs.

All the plates and washers are fitted on and keyed to a sleeve threaded at the ends and equipped with nuts and collars for drawing the thick end-plates together or, if desired, the collars may be simply forced onto it and the ends upset. The sleeve has a hole fitting snugly on the shaft and is fastened to the same as usual.

This construction permits free expansion and contraction of each plate individually under the varying influence of heat and centrifugal force and posesses a number of other advantages which are of considerable practical moment. A larger active plate area and consequently more power is obtained for a given width, this improving efficiency. Warping is virtually eliminated and smaller side clearances may be used which results in diminished leakage and friction losses.

The rotor is better adapted for dynamic balancing and through rubbing friction resists disturbing influences thereby insuring quieter running. For this reason and also because the discs are not rigidly joined it is safer against damage which might otherwise be caused by vibration or excessive speed.

Dated this 24th day of March, 1921.

NIKOLA TESLA.

COMPLETE SPECIFICATION.

Improvements in the Construction of Steam and Gas Turbines.

I, NIKOLA TESLA, Electrical and Mechanical Engineer, citizen of the United States of America, of No. 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In a British Patent, No. 24,001 of 1910, I have described a bladeless turbine having a rotor consisting of discs with openings in the central portions, and separating star-washers, these parts when assembled being riveted together into a single solid structure and keyed to the shaft. This form of rotor operates satisfactorily but in long experience certain improvements in its construction have been found desirable and these constitute my present invention.

In the new design, illustrated in the accompanying drawings Fig. 1 and Fig. 2, respectively showing a section through the rotor on line II and a side view partly broken away exposing a portion of a star-washer, I preferably employ two heavier end-plates 1, 1 of suitable material made tapering on the outside toward the periphery, as shown, for the purpose of reducing the maximum centrifugal stress as much as practicable. The inside discs 2, 2 . . . . are relatively thin and may be tapered on both sides in the peripheral part beyond the star-washers with the same object in view, but plates of substantially uniform thickness, as furnished by the mills, can also be employed. Each of the plates—thick as well as thin—is provided with exhaust openings 3, 3 . . . . leaving a solid central portion 4, 4 . . . . like the hub and spokes of a wheel. If there is an odd number of thin plates the central one may be plain, if desired. Star-washers 5, 5 . . . . of similar configuration, and projecting with their arms considerably beyond the exhaust openings, serve the purpose of keeping the discs apart in the central region and for the peripheral spacing the thin plates have small holes drilled in them preferably on a circle, or circles, of suitable diameter, and in these are driven tight-fitting spacers or studs 6, 6 . . . . which may be upset at the ends so that they will project on each side a trifle more than the thickness of the star-washers 5, 5 . . . . When the plates are put together the separating studs do not come in line but are straddled, as indicated in Fig. 1 and in the broken away part of Fig. 2 by the plain and dotted small circles, in order to give opportunity for slight yielding, thereby eliminating constructional difficulties which might be caused by unevenness or other mechanical imperfections. Such a rotor can be finished closely to predetermined overall dimensions and will run true on the outside even if the thin inside plates should vary a little in thickness or be slightly warped. To simplify the construction I provide only every second plate with studs, using plain ones between. Furthermore, with the object of cheapening the manufacture, I may dispense with the studs altogether, accomplishing the peripheral spacing by means of other spacers such as small bosses or protuberances raised in the plates, thus reducing the machine work on the thin ones to a single operation in a stamping press. The star-washers, while preferable, are not indispensable and may be replaced by round separating washers of a diameter about equal to that of the hub part of the discs.

All the plates and washers are fitted on and keyed to a sleeve 7, threaded at the ends and equipped with nuts 8, 8 for drawing the thick end-plates together or, if desired, the nuts and threads on the sleeve may be omitted, collars forced on its ends and the same upset. The sleeve fits snugly on the shaft 9 and is fastened to it as usual.

This construction enables the use of thinner inside plates then practicable in the earlier form, thus affording a greater active surface and increasing correspondingly the output, while the smaller clearances are instrumental in reducing the leakage losses.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A rotor for steam and gas turbines

composed of plane spaced discs and two rigid end-plates holding them in fixed position laterally but permitting their independent expansion or contraction in the radial direction, said discs and plates being provided with exhaust openings in their central portions, substantially as described.

2. A turbine rotor comprising plane discs with spacers allowing radial displacement, central separating washers and two rigid tapering end-plates for holding the structure firmly near the shaft, said discs and end-plates having exhaust openings in their central portions, substantially as described.

3. In a rotor for high-speed turbines plane spaced discs with exhaust openings in their central portions and tapering towards the periphery as, and for the purpose, described.

4. A turbine rotor consisting of a system of discs held apart by spacers in frictional contact with them and alternately straddled as, and for the purpose, described.

5. A turbine rotor composed of plane parallel discs having exhaust openings in their central portions and projections for holding them apart near the periphery, substantially as described.

6. In a turbine rotor composed of flat discs with exhaust openings in their central portions, star washers of similar configuration and projecting with their arms considerably beyond the openings in the discs, substantially as described.

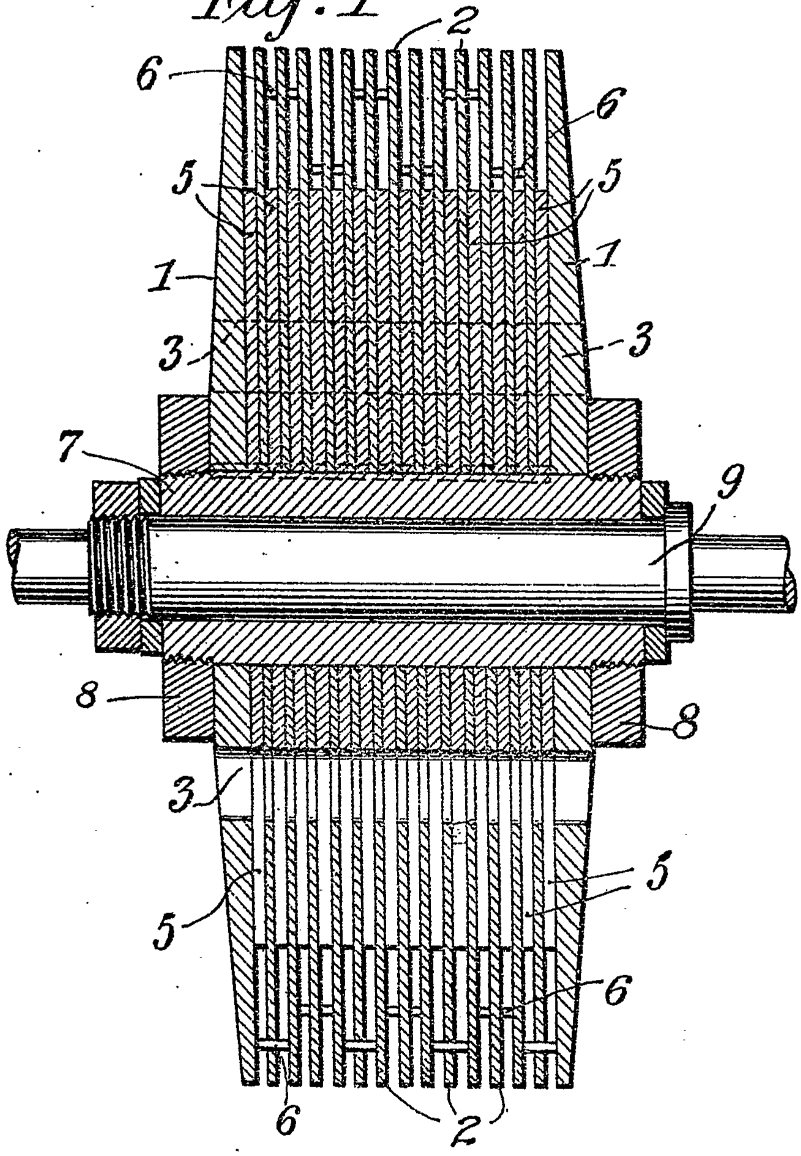
Dated the 23rd day of August, 1921.

NIKOLA TESLA.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1922.

[This Drawing is a full-size reproduction of the Original.]

Fig. 1



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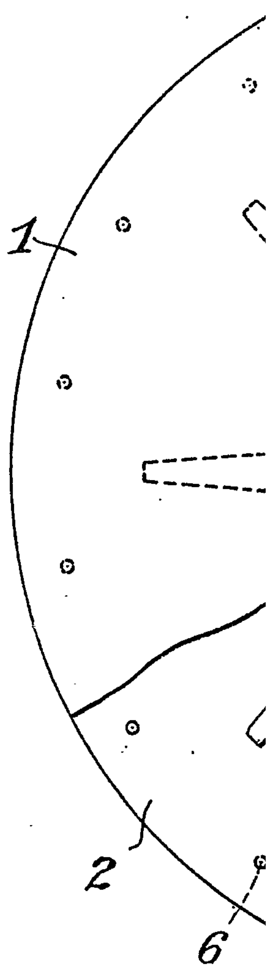
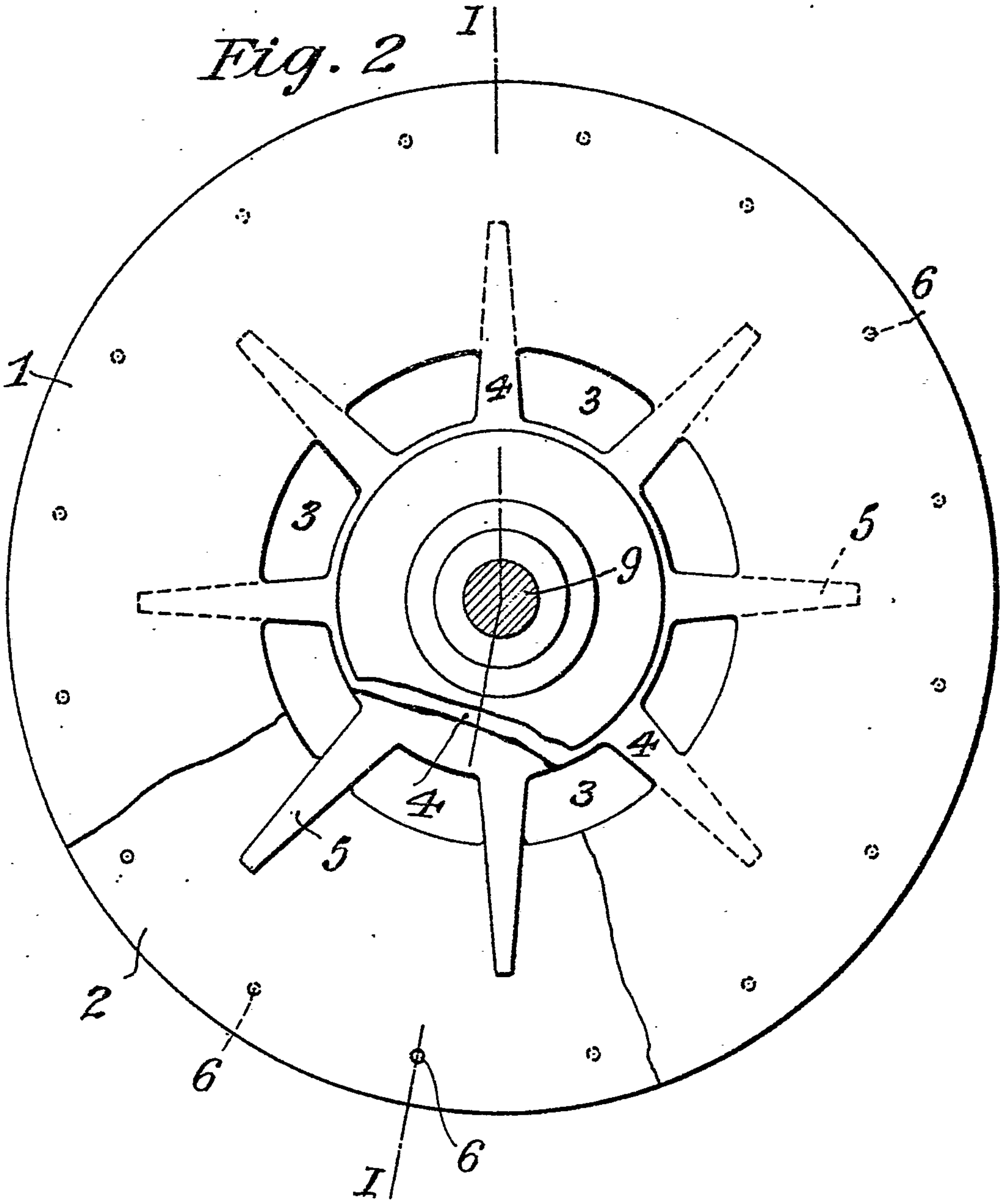


Fig. 2



Malby & Sons, Photo-Litho

[This Drawing is a full-size reproduction of the Original.]

Fig. 1

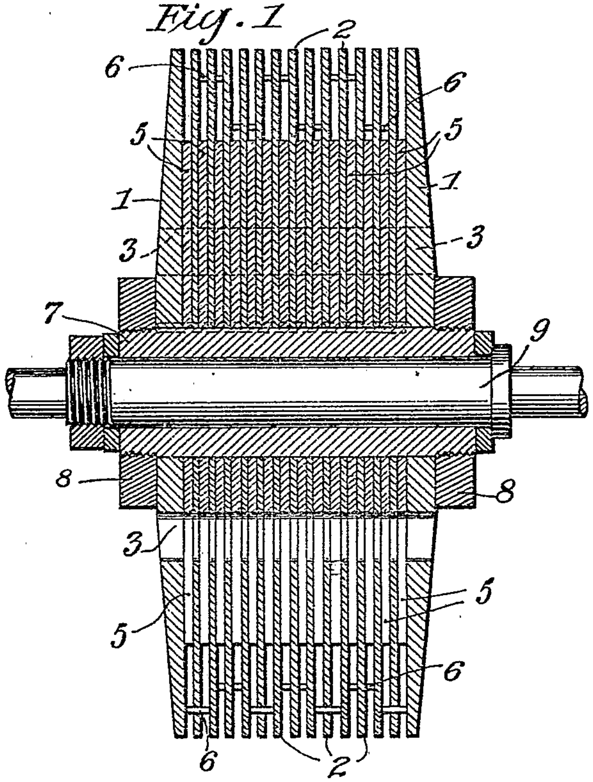
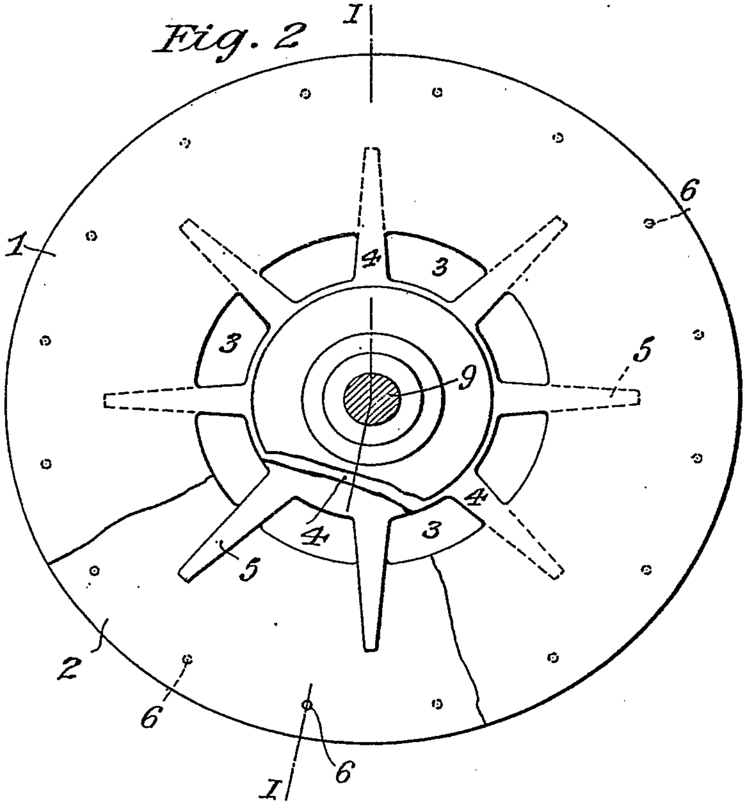


Fig. 2



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PATENT SPECIFICATION

Application Date: Mar. 24, 1921. No. 9099/21.

186,083

Complete Left: Sept. 5, 1921.

Complete Accepted: Sept. 25, 1922.

PROVISIONAL SPECIFICATION.

Improved Method of and Apparatus for the Economic Transformation of the Energy of Steam by Turbines.

I, NIKOLA TESLA, Mechanical and Electrical Engineer, citizen of the United States of America, of 8, West 40 Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

The chief object of my improvements is to increase the efficiency of the existing steam power plants and thermo-dynamic transformers operated therefrom, but they may also be applied with like effect apart from the present establishments and are intended for the broad purpose of producing motive power, more economically, through the medium of steam.

It is well-known that notwithstanding the multiplication of hydro-electric and gas engine installations, steam is still the main source of power, but as a rule only a low fuel efficiency is secured owing to limitations inherent to the thermal process itself, as now carried out, and certain shortcomings of the present forms of apparatus. Furthermore, plans which have been heretofore contemplated for the attainment of better economy generally involved technical obstacles, more or less radical changes and necessarily considerable expense. For instance, in order to minimize the heat losses incident to the raising of steam, it has been suggested to burn the fuel together with air in the boiler and operate the engines by the mixture of steam and gas thus obtained. So far, however, attempts to effect combustion satisfactorily under such conditions have not been very successful. High pressures hape been proposed with the same end in view but no great progress has yet been made in that direction; in fact many engineers view such projects with disfavor as they present a number of objectionable features and the possibilities of improvement are circumscribed. Again the employment of superheat as a means of increasing fuel efficiency is practicable only in a measure because the adopted types of prime movers do not lend themselves to high temperatures which, in conformity with the fundamental laws of thermodynamics, are indispensable to such a full realization.

These drawbacks have been successfully overcome in the method I have devised, which is very economical, readily applicable to the plants now in operation without appreciable modifications in them, and is rendered particularly advantageous through the instrumentality of a turbine or rotary engine described in my British Patent No. 24,001 of 1910 and improvements I have made in its construction since that time. This machine is capable of operating satisfactorily at very high temperatures, with cheap fuel, containing a large percentage of impurities, and without substantial impairment of efficiency as might be due to oxidation, roughening of the metal surfaces, or similar deteriorating actions which seriously interfere with the working of other heat engines now in use.

In applying my invention to a steam power plant I use air, under a pressure about equal to that of the boiler, for burning gas, crude oil, colloidal fuel or powdered coal in a chamber or conduit into which the steam is simultaneously admitted as cooling agent and diluent. The provisions to this end will greatly vary according to conditions. In central stations, factories, on shipboard and in many other places compressed air, as well as steam, is available and often, too, all the facilities for fuel storage and supply

[*Price* 1/-]

may be on hand. In such cases the benefits of my improvements will be readily derived with but little additional apparatus and at small cost. If the circumstances require, I provide an air- and also a gas compressor when necessary, driven directly from the shaft of the prime-mover or operated independently by electricity, steam or other motive agent. Generally these machines will be of the more efficient reciprocating type, but rotary compressors or both may be employed to secure some advantage. Irrespective of specific arrangements I effect the combustion while the fluids are in rapid motion and in a conduit preferably in close proximity to the engine, thus disposing of most of the difficulties previously encountered and at the same time materially reducing the radiation and conduction losses which would be incurred in the passage through long pipes. To better insure the maintenance of standard working conditions I may add to the equipment an equalizer of pressures operated differentially by the air and steam, but this device is not essential. The quantity of steam is so regulated that the highly heated mixture, upon expansion through the nozzle, attains an arbitrary temperature which the turbine can safely withstand. The elastic fluids, after traversing the rotor and giving up to the same a part of their kinetic energy, escape through the exhaust openings and serve the further purpose of preheating the feedwater, fuel, and likewise the air when desired. If intensely heated, the air and fuel will be conveyed to the combustion chamber separately, but in small installations it may be convenient to feed the fuel into the compressor or air pipe leading the carburated medium to the chamber. When simplicity is paramount, cheap coils or heaters for the combustibles and the feedwater will be resorted to, but in order to attain a still higher thermal efficiency I employ, besides, a small auxiliary boiler through which the exhaust is circulated. The steam thus obtained from waste heat is fed through a suitable valve, opening at the proper pressure, into the combustion space whence it passes, together with that furnished by the plant, through the turbine first doing useful work and then adding to the waste heat to be utilized in the manner set forth. More fuel may now be gradually admitted to maintain the normal temperature, this again increasing the heat in the exhaust and causing a more rapid generation of the steam, and so on, until finally a steady regime is established. However, if deemed of advantage under given operative conditions, the steam from the main boiler may be reduced in quantity in approximately the same measure as that from the auxiliary boiler is supplied.

This plan provides an efficient self-starting prime mover which may be operated as a steam- or mixed fluid turbine at will, without constructional change and is on this account very convenient. Minor departures from it, as may be dictated by the circumstances in each case, will obviously suggest themselves but if it is carried out on these general lines it will be found highly profitable to the owners of the steam plant while permitting the use of their old installation. However, the best economic results in the development of power from steam by my invention will be obtained in plants especially adapted for the purpose. It should be added that this method can also be successfully applied to condensing plants operating with high vacuum. In such a case, owing to the very great expansion ratio, the exhaust mixture will be at a relatively low temperature and suitable for admission to the condenser. Better fuel has to be used and special pumping facilities provided but the economic results attained will fully justify the increased outlay.

Dated this 24th day of March, 1921.

NIKOLA TESLA.

COMPLETE SPECIFICATION.

Improved Method of and Apparatus for the Economic Transformation of the Energy of Steam by Turbines.

I, Nikola Tesla, Electrical and Mechanical Engineer, citizen of the United States of America, of No. 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The chief object of my improvements

is to increase the efficiency of existing steam power plants and thermodynamic transformers operated therefrom, but they may also be applied with like effect apart from the present establishments and are intended for the broad purpose of producing motive power, more economically, through the medium of steam mixed with the heated products of combustion, while the apparatus is capable of actuation by steam alone. It is well-known that notwithstanding the multiplication of hydro-electric and gas engine installations, most of the motive power is still derived from this agent, but only a relatively low fue efficiency is secured owing to limitations inherent to the thermal process itself, as now carried out, and certain shortcomings of the present forms of apparatus. These drawbacks have been largely overcome in the method I have devised, which is very economical, readily applicable to the plants now in operation without substantial modifications in them, and is rendered particularly advantageous through the instrumentality of a turbine or rotary engine described in my British Patent No. 24,001 of 1910 and improvements I have made in its construction since that time. This machine is capable of operating satisfactorily at very high temperatures, with cheap fuel containing a large percentage of impurities, and without material impairment of efficiency as might be due to oxidation, roughening of the metal surfaces or similar deteriorating actions which seriously interfere with the working of other heat engines.

In applying my invention to a steam power plant I use air, under a pressure about equal to that of the boiler, for burning gas, crude oil, colloidal fuel or powdered coal in a chamber or conduit, the products of combustion escaping from the same mixing with the steam on their way to the turbine being thus diluted and cooled to the desired temperature. The provisions to this end will greatly vary according to conditions. In central stations, factories, on shipboard and in many other places compressed air, as well as steam, is available and often, too, all the facilities for fuel storage and supply may be on hand. In such cases the benefits of my improvements will be readily derived with but little additional apparatus and at small cost. If the circumstances require, I provide an air- and sometimes also a gas-compressor driven either directly from the shaft of the primemover or independently by electricity, steam or other motive agent. Generally these machines will be of the more efficient reciprocating kind, but rotary compressors or composite types may be employed to secure some advantage. Irrespective of specific arrangements, I effect the combustion and mixing while the fluids are in rapid motion in a conduit which is, preferably, in close proximity to the turbine, thus disposing of most of the abovementioned difficulties previously encountered and at the same time considerably reducing the radiation and conduction losses which would be incurred in the passage through long pipes. To better insure the maintenance of standard working conditions, I may add to the equipment a device of the usual construction for equalizing the steam and air pressures. The quantity of steam is so regulated that the highly heated mixture, upon expansion through the nozzle, enters the turbine at a temperature which the machine can safely withstand. The elastic fluids, after traversing the rotor and giving up to the same a part of their kinetic energy, escape through the exhaust openings and may serve the further purpose of preheating the feedwater, fuel, and likewise the air when desired. If intensely preheated, the air and fuel will be conveyed to the combustion chamber or conduit separately, but in small installations it may be convenient to feed the fuel into the compressor or the air pipe thus bringing about a thorough mixture of the combustibles. When simplicity is of paramount importance, heaters may be resorted to for improving the economy, but in order to attain a still higher thermal efficiency I provide a boiler through which the working fluids, exhausted from the turbine, are circulated. The steam thus obtained from waste heat is fed through a suitable valve, into an inlet pipe whence it passes either separately or together with the mixed working fluid through the nozzle, first doing useful work and then adding to the waste heat of the exhaust. More fuel may now be gradually admitted to maintain in the inlet pipe the normal temperature, thus again increasing the heat in the exhaust and causing a more rapid generation of the steam, and so on, until finally a steady regime is established. However, if deemed of advantage under given operative conditions, the steam furnished by the plant may be reduced in quantity in approximately the same measure as that from the boiler is supplied.

My invention will be more fully understood by reference to the accompanying drawings in which Figure 1 illustrates the general arrangement of the apparatus comprising the turbine, a compressor, a storage tank for the fuel, a boiler and the necessary pipe connections and controlling devices, and Figure 2 a vertical cross-section of the main valve for admission of the steam and regulation of its flow.

In the first named figure, 1 represents my turbine with its shaft flexibly coupled to a machine performing useful work, as dynamo 2. The general construction of the turbine is preferably as described in my British Patent No. 24,001 of 1910, two nozzles being provided, which are intended to operate in the same direction. The nozzles are contained in two diametrically opposite enlargements of the casing and communicate with inlet pipes 3 and 4 which are joined, through suitable valves 5 and 6, to the main steam admission and control valve 7, shown in section Figure 2 and to be described in detail.

The air compressor can be of any kind but is shown of the reciprocating high speed type, driven by an electric motor 8, and comprising two stages 9 and 10, with an intercooler 11. A pipe 12 carrying valve 13, connects the discharge duct of the compressor to flanged conduits 14 and 15 which are bolted to the inlet pipes 3 and 4 as indicated and equipped with means for ignition, as spark plugs 16 and 17. An extension 18 of pipe 12 leads through a valve 19, to the top of the fuel tank 20 and serves the purpose of maintaining in the latter the required pressure. When the employment of an air reservoir is deemed preferable extension 18 will be put in communication with the same through valve 21. A filling pipe 22, armed with valve 23, is attached to the top of tank 20 while near to its bottom is joined a discharge pipe 24 provided with valve 25 leading through a needle valve 26 to an automatic control valve 27 which is connected by pipes 28 and 29 to the flanged conduits 14 and 15.

The main valve 7 is designed for control of the steam flow both by automatic means and independently of the same. Its construction is clearly indicated in Figure 2, representing a vertical cross-section. The device consists of a casting 30 with inlet ports 31 and outlets 32 and 33, which are joined by flanges to pipes 3 and 4. The open bottom of the casting is connected to a steam inlet pipe 34 while the top carries a throttle valve 35 for turning on and shutting off the steam. Below the seat of this valve the casting has a transversal bore, into which is freely fitted a hollow cylinder 36 with balanced intake and exhaust openings, the latter registering with outlets 32 and 33 in the casting. The cylinder 36 is rigidly joined through a rod 37 with a hollow plunger 38 (Fig. 1) having diametrically opposite ports matching those in the stationary part of valve 27.

The boiler 39, which may be of the vertical tubular type as illustrated, is connected through its headers 40 and 41 on the lower end to main 42 communicating with the exhaust opening 43 of the turbine, and on the upper one to discharge conduit 44 through which the hot fluids, after traversing the boiler tubes, escape into the atmosphere or are led to an economizer for preheating the feed-water or otherwise utilizing the waste heat. A conduit 45 joins the top of the boiler to inlet pipe 3 through a suitable valve 46 which may be operated either by hand or automatically.

From the foregoing the operation will now be readily understood. At the start valve 46 being closed and 5 and 6 open, steam from the plant is admitted through throttle and control valve 7 whence it passes into the inlet pipes 3 and 4 and communicating nozzles from which it issues at high velocity setting the rotor in motion, the machine operating purely as a steam turbine. The spark plugs 16 and 17 are then brought into play and valves 13, 19 and 25 opened, the latter allowing the fuel to flow from the tank, chiefly under the action of gravity, to needle valve 26 which is gradually turned on. The fuel thereupon passes through the ports of hollow plunger 38 and pipes 28 and 29 into apparatus for mixing and combustion, the construction of which is clearly shown in the cross-section at the lower branch, it being understood that the arrangement on the upper branch is identical. As will be seen the conduit 15 is armed on one end with a spraying device and on the other with a funnel-shaped extension which is held tight between flanges and projects far into the steam inlet pipe 4. The fuel, atomized by the inrushing air, enters the combustion chamber formed by an enlargement in conduit 15, and is then ignited in the same, the products of combustion escaping into the inlet pipe 4 and mixing with the steam on their way to the nozzle. This kind of apparatus overcomes the difficulty heretofore encountered in attempts to effect combustion practically and will work satisfactorily even if there are considerable fluctuations in the steam and air pressures, as the faster moving fluid aspirates the slower one. It has been assumed that liquid fuel is used but powdered coal may also be employed in substantially the same manner with slight constructive modifications, the powder being conveyed to the combustion chamber either independently of, or with, the air. The quantity of the combustibles is so regulated by manipulation of valves 13 and 26 (and also 5, 6 and throttle 7, if suitable) that the mixture, escaping from the nozles, will be at a temperature considered safe for the operation of the turbine. To facilitate this any of the well-known compound valves may be provided for the purpose of admitting the combustibles always in the required proportions irrespective of their total quantity.

When the steam in boiler 39, raised by the exhaust mixture passing through the tubes, attains the required pressure, it is admitted through valve 46, conduit 3 and corresponding nozzle, to the rotor, adding kinetic energy to the same. Feed-water, preferably heated by the turbine exhaust, is supplied to the boiler in the same measure as steam is drawn off, any ordinary means to this end being employed.

The automatic control of the flow of steam and fuel may be effected by any kind of speed governor operatively connected to rod 37 so that the supply is reduced as the speed increases. In addition to the means shown, an air valve may be provided, actuated automatically by the governor either through rod 37 or otherwise. For further convenience and to enable the independent control of the air and fuel supply in the two branches, conduits 14, 15 and pipes 28, 29 may be equipped with valves, indicated in Fig. 1, the numbering of which is deemed unnecessary.

The amount of power obtainable from boiler 39 will vary according to conditions. Turbines as described in my said prior specification are capable of operating at a very high exhaust temperature and then the energy recovered from the waste heat in this manner may be a large fraction of the whole useful work. In such as case conduit 3, pipes 14 and 28 together with all their adjuncts, as illustrated, can be omitted and the steam supplied directly to the nozzle through valve 46. Or these connections and adjuncts may be left undisturbed and a separate nozzle provided. In admitting the steam from the boiler to the turbine rotor through independent channels, the practical advantage is secured that the pressure may vary considerably without detracting much from the efficiency of the machine, which will be improved through preheating of the combustibles by any of the well-known means.

This plan provides an efficient self-starting mixed-fluid turbine which may also be operated with steam alone, merely by shutting off the air and fuel supply, and is on this account very convenient. Minor departures from it, as may be dictated by the circumstances, will obviously suggest themselves, but if it is carried out on these general lines it will be found highly profitable to the owners of the steam plant while permitting the use of their old installation. However, the best economic results in the development of power from steam by my invention will be obtained in plants especially adapted for the purpose. It should be added that this method can also be successfully applied to condensing plants operating with high vacuum. The production and maintenance of the latter will be materially facilitated by the employment of a pump as shown in my British patent before referred to. In such instances, owing to the very great expansion ratio, the exhaust mixture will be at a relatively low temperature and suitable for admission to the condenser. This will call for better fuel and special pumping facilities, but the economic results attained will fully justify the increased outlay.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. In a turbine installation normally working with a mixture of steam and products of combustion and in which the exhaust heat is used to provide steam which is supplied to the turbine, providing a valve governing the supply of such last mentioned steam so that the pressures and temperatures can be adjusted to the optimum conditions of working.

2. A turbine installation as described and claimed in Claim 1 so arranged that it is capable of starting with steam alone.

3. A turbine installation as described and claimed in Claim 1 or 2 in which the turbine is of the friction disc type adapted to work with fluids at a very high temperature such as is described in Specification 24,001 of 1910.

4. The combined apparatus substantially as described and shown in the drawings.

Dated the 23rd day of August, 1921.

NIKOLA TESLA.

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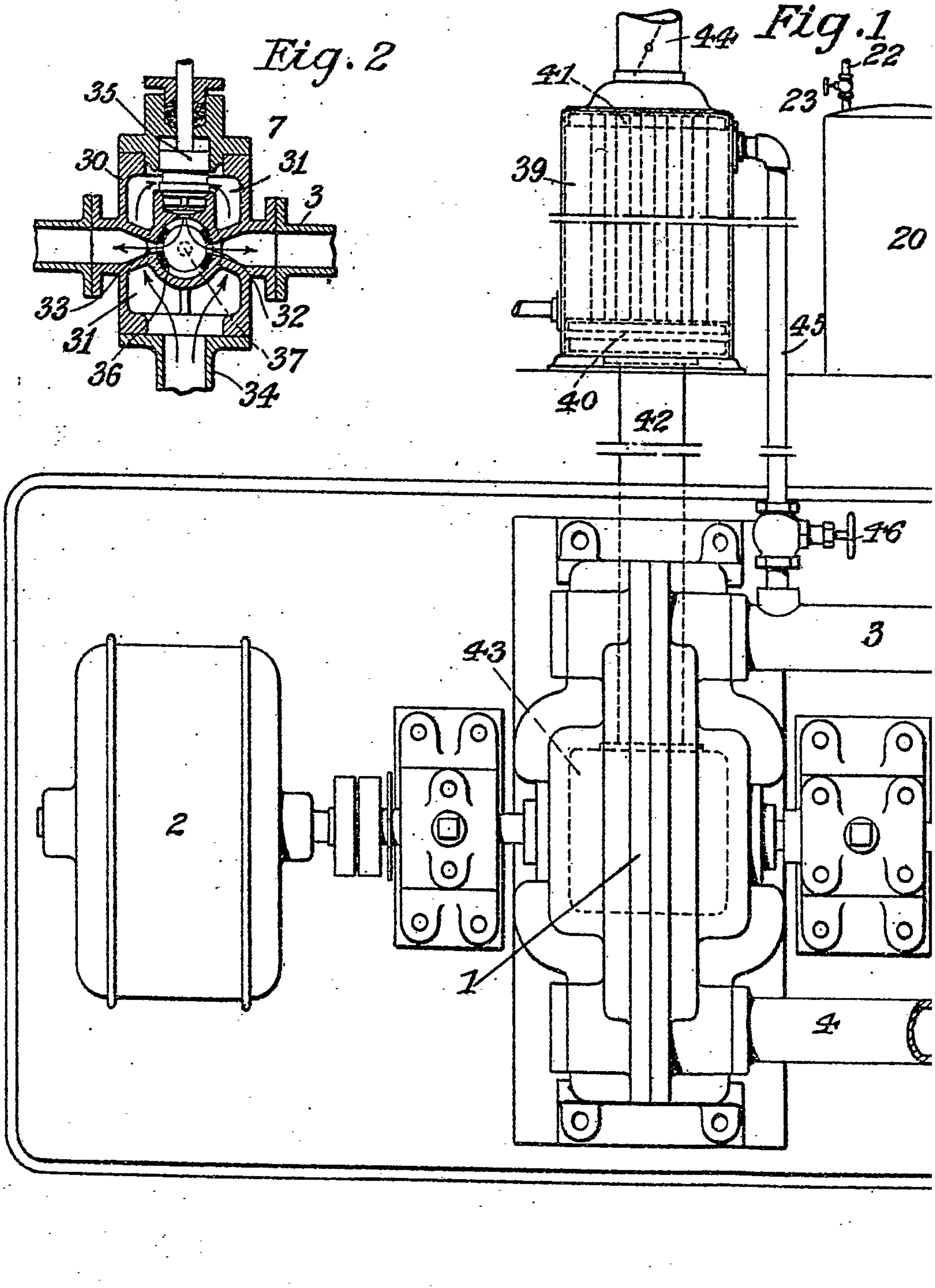
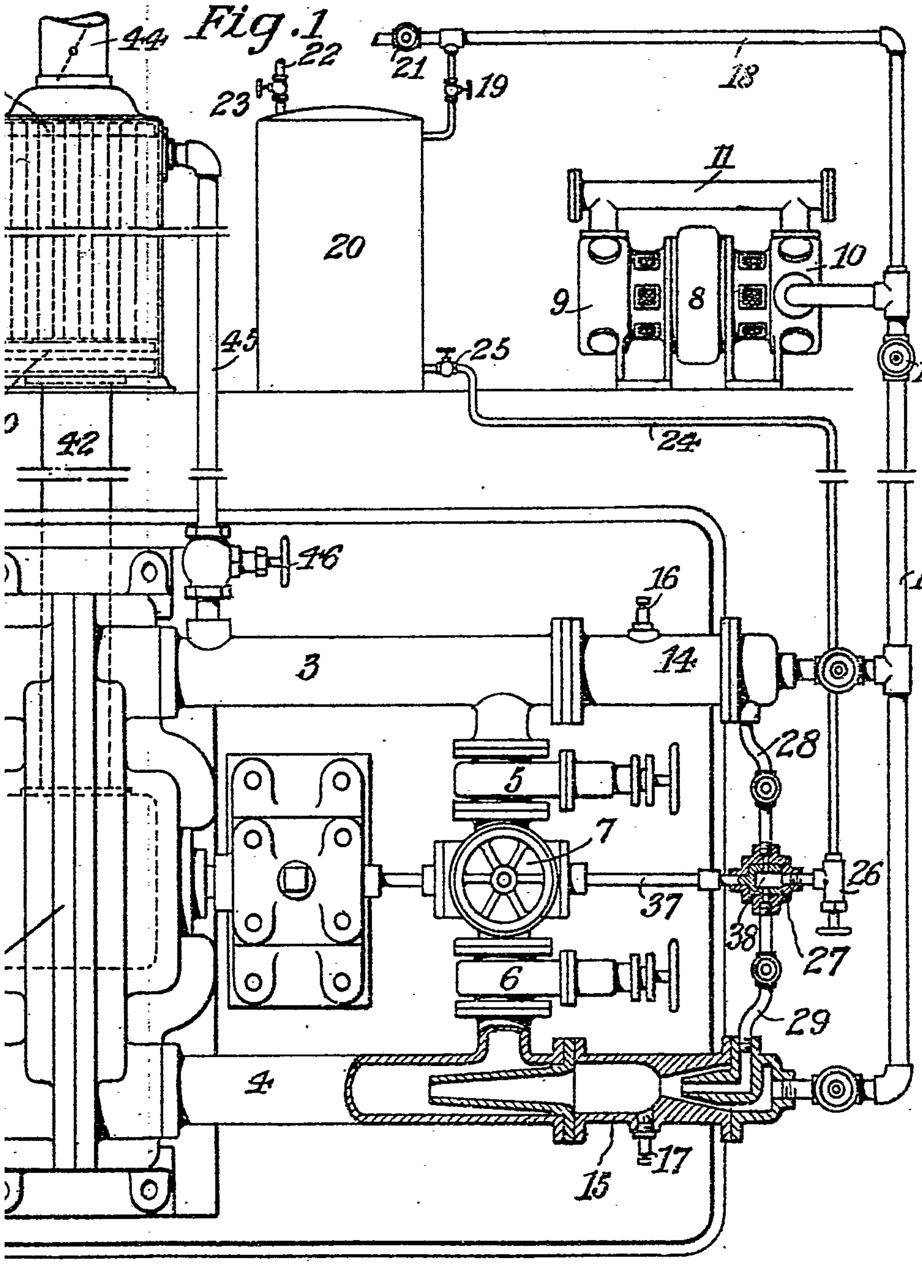
Fig. 2

Fig. 1



1 SHEET

Fig. 1



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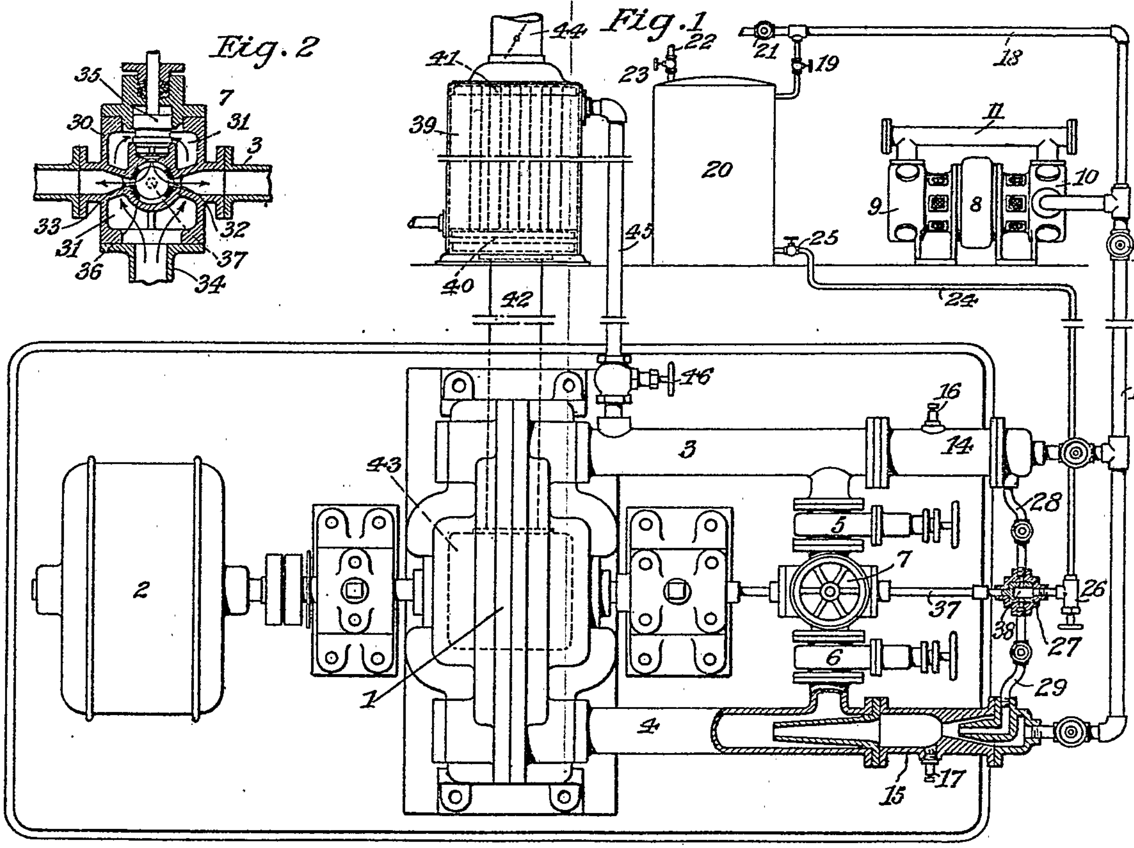

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PATENT SPECIFICATION

Application Date: Mar. 24, 1921. No. 9100/21.

Complete Left: Sept. 2, 1921.

Complete Accepted: Sept. 25, 1922.

186,084

PROVISIONAL SPECIFICATION.

Improved Process of and Apparatus for Deriving Motive Power from Steam.

I, Nikola Tesla, Mechanical and Electrical Engineer, Citizen of the United States of America, of 8, West 40 Street, New York City, U.S.A., do hereby declare the nature of this invention to be as follows:—

This improvement provides a very simple means for increasing the economy of steam turbines and is chiefly intended to be used in the operation of small units but may also be applied, with more or less success, to machines of considerable capacity, the saving effect depending largely on the conditions existing in the steamplants where it is introduced. The economic gain will be especially pronounced in factories and industrial establishments in which the steam pipes are long and serious loss is incurred through condensation and otherwise. The apparatus for carrying out the process is capable of slight modifications and can be employed in conjunction with different types of turbines, but is particularly suited to that described in my British Patent No. 24,001 of 1910, in which propulsion is effected by the adhesive and viscous action of the motive fluid. Irrespective of constructive features the general arrangement will be as follows:

The steam from the boiler is led through a superheater to the turbine nozzle and the high velocity jet projected from it against the rotor creates a suction in the adjacent space which is connected to the superheater pipes or coils, thus causing a strong air current to pass through the same. The air first enters a chamber to which gas or other fuel is supplied and the products of combustion are aspired through the coils into the turbine, superheating the steam to the desired degree, also increasing the temperature of the stream through the turbine rotor and, incidentally, imparting to it some of their kinetic energy. All of these actions co-operate in raising the efficiency of the machine with the result of bringing about an important reduction of operative expense.

To improve the performance of the apparatus I employ two concentric nozzles, steam being admitted to the turbine through one and the products of combustion through the other. Furthermore, in order to turn to good use the waste heat of the exhaust I attach to the latter an economiser for preheating the feedwater and fuel, thereby effecting additional saving.

This invention dispenses with the compressor ordinarily required in connection with a gas turbine and will be found valuable on account of its extreme simplicity, low cost of installment and facilities it affords.

Dated this 24th day of March, 1921.

NIKOLA TESLA.

COMPLETE SPECIFICATION.

Improved Process of and Apparatus for Deriving Motive Power from Steam.

I, Nikola Tesla, Electrical and Mechanical Engineer, citizen of the United States of America, of 8, West 40th Street, New York, N.Y., U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This improvement provides a very

simple means for increasing the economy of steam turbines and is chiefly intended to be used in the operation of small units but may also be applied, with more or less success, to machines of considerable capacity, the saving effect depending largely on the conditions existing in the steam-plants where it is introduced. The economic gain will be especially pronounced in factories and industrial establishments in which the steam pipes are long and serious loss is incurred through condensation and otherwise. The apparatus for carrying out the process is capable of slight modifications and can be employed in conjunction with different types of turbines, but is particularly suited to that described in my British Patent No. 24,001 of 1910, in which propulsion is effected by the adhesive and viscous action of the motive fluid. Irrespective of constructive features the operation will be generally as follows:

The steam from the boiler is led to the nozzle through a superheater, which should be placed as near as possible to the turbine, and the high velocity jet, projected from it against the rotor, creates a suction in the adjacent space which is connected to the superheater pipes or coils, thus causing a strong air current to pass through the same. The air first enters a combustion chamber to which gas or other fuel is supplied and the products are aspirated through the coils into the turbine, superheating the steam to the desired degree, also increasing the temperature of the stream through the turbine rotor and, incidentally, imparting to it some of their kinetic energy. All of these actions co-operate in raising the efficiency of the machine with the result of bringing about an important reduction of operative expense.

To improve the performance of the apparatus, I preferably employ two concentric non-convergent nozzles, steam being admitted to the turbine through one and the products of combustion through the other. Furthermore, in order to turn to good use the waste heat of the exhaust I may attach to the latter an economiser for preheating the feed-water and fuel, thereby effecting additional saving.

The preferred form of apparatus for carrying out the process above described is illustrated in the accompanying drawings in which Fig. 1 is a side view in elevation, partly cross-sectioned, and Fig. 2 a vertical section through one of the parts for supplying steam and combustion products to the turbine.

Referring to the figures more specifically, 1 is the rotor and 2, 2 the enclosing casing of the turbine which is provided with two diametrically opposite enlargements 3, 3 bored out and fitted with concentric conduits 4, 4 and 5, 5 for supplying the working fluids to the rotor. These are equipped with, or form part of, corresponding discharge nozzles 6, 6 and 7, 7. The superheater consists of a steam-chamber 8 closed at the ends by plates 9 and 10 and containing a coiled pipe 11, the ends of which are led out, one being connected to a combustion chamber 12 and the other to an outlet pipe 13 with branches 14 and 15 leading to the inner supply channels 16, 16. Steam inlet and outlet pipes, respectively, 17 and 18, are provided, the latter with two branches 19 and 20 communicating with channels 21, 21 of the supply part. Suitable steam, air and gas inlet valves, respectively marked 22, 23 and 24 may be employed for controlling and regulating the supply of the working fluids to the turbine. All the supply channels should be of a section sufficiently large so that the velocities of the fluids through them will be small as compared with those attained in the nozzles.

The operation will now be readily understood. Valves 23 and 24 being closed, the steam admitted by valve 22 passes through inlet pipe 17, chamber 8, outlet 18, branches 19 and 20, spaces 21, 21 and nozzles 6, 6, setting the turbine rotor in motion thus operating the machine as a simple steam turbine subject to the usual limitations in economic performance. The inlet valve 23 is now opened permitting the atmospheric air to be drawn in through coil 11, pipe 13, branches 14 and 15, channels 16, 16 and nozzles 7, 7 to the rotor. Power gas or other fuel is then admitted through valve 24 and upon being ignited in the combustion chamber 12 the products pass through in like manner, assisted by their initial velocity. As a result of this action, coiled pipe 11 is heated to a high temperature and superheats the steam in chamber 8 and also in the supply channels and nozzles, thus adding very materially to the available energy of the steam, at the same time increasing the efficiency of thermodynamic transformation. The products of combustion themselves, impinging against the rotor, contribute usefully some of their kinetic energy. The economic gain effected in this simple manner will be all the more pronounced the poorer the initial quality of the steam and the higher the pressure supply. However, low-pressure steam, as that exhausted from turbines or reciprocating engines, may likewise be economically utilized by this process and means, especially if provision is made for maintaining a vacuum at the exhaust end of the turbine.

The apparatus described is capable of minor modifications. For instance, the combustibles may be admitted to the rotor through the outer channels and steam through the inner ones. Again, the nozzles instead of being co-axial, as shown, may be otherwise constructed and disposed, or single nozzles may be used in their place and the mixture of the steam and gases effected before admission to them. However, this can be more or less completely accomplished with co-axial nozzles, as illustrated, merely by shortening one of them. As to the superheater it may be of widely varied design and incorporated with the turbine casing for the purpose of saving energy, weight and space. Departures may also be made in the design of the combustion chamber to suit the fuel employed and the necessary adjuncts for carburation and ignition will be provided, all of which, being well-known, are omitted from the drawing for the sake of clearness. Obviously, the process can be applied with more or less success in the transformation of the heat energy of elastic fluids other than steam.

This invention provides a self-starting, compact and efficient mixed-fluid turbine and will be found valuable on account of its extreme simplicity, low cost of instalment and the facilities it affords.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The hereinbefore described process of thermo-dynamic transformation of energy which consists in admitting steam to a turbine nozzle, aspirating by the suction thus created hot products of combustion through a heater, superheating the steam by them and discharging them at high velocity and in a direction parallel to the steam-jet upon the rotor, as described.

2. The process of increasing the efficiency of steam as motive agent which consists in admitting it through a heater to a turbine nozzle, aspirating by the suction thus created hot products of combustion through the heater thereby raising the temperature of the steam to a high degree and discharging the products at high velocity and in contact with the steam-jet upon the rotor, as described.

3. The method of operating a mixed fluid turbine which consists in starting it by steam admitted to the nozzle, aspirating by the suction produced in the space adjacent to the same hot products of combustion, superheating the steam by them and directing them upon the rotor so as to assist in driving it, as described.

4. The herein described process and apparatus by which a turbine rotor is started by steam and combustible fluids are aspirated by the suction of the steam-jet into a combustion chamber, the products of combustion serving to superheat the steam and then assist in driving the rotor.

5. In the process described and claimed in Claims 1, 2 and 3, the use of a friction turbine of very small windage.

6. In the process and apparatus described and claimed in Claim 4, the use of concentric non-convergent nozzles opening directly into the rotor chamber of the turbine.

7. In a mixed fluid turbine in which a secondary fluid is aspirated by the suction of the primary, the employment of non-convergent co-axial nozzles for discharging the fluids in parallel contacting streams upon the rotor, as described.

Dated the 23rd day of August, 1921.

NIKOLA TESLA.

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[This Drawing is a reproduction of the Original on a reduced scale]

Fig. 1

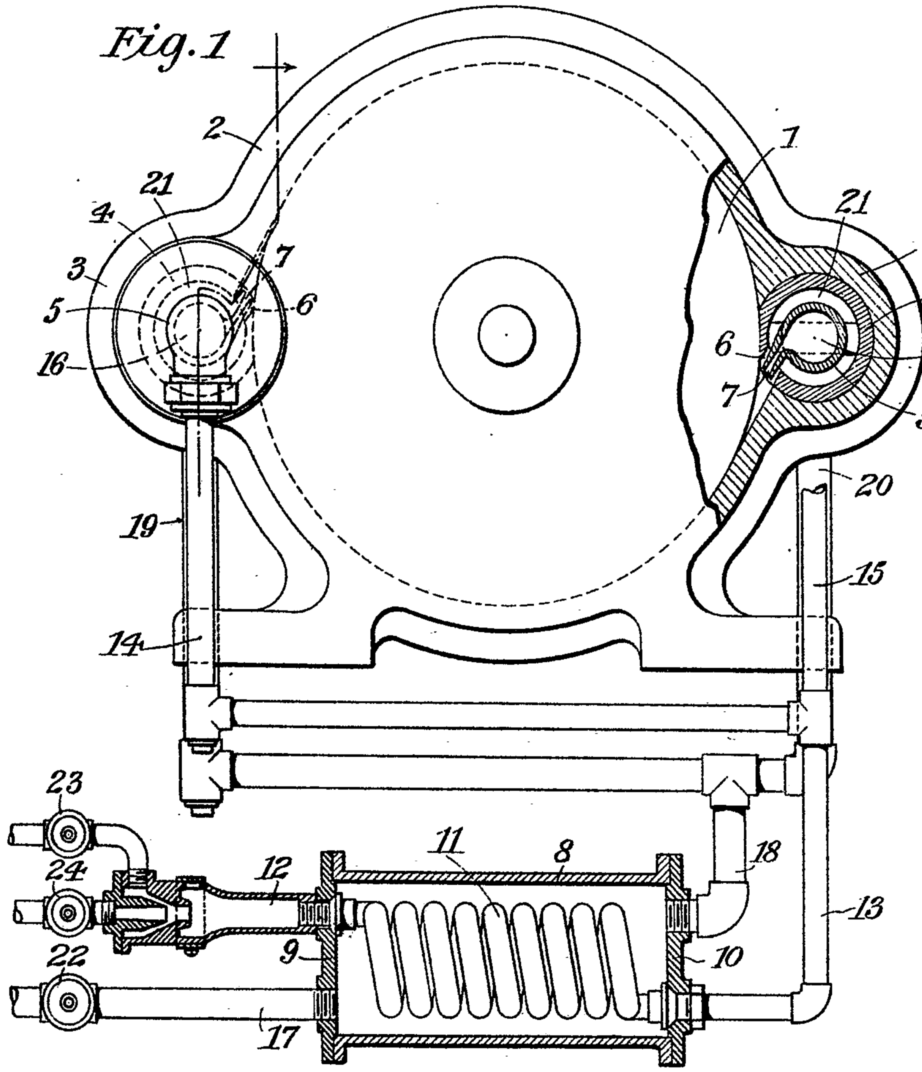
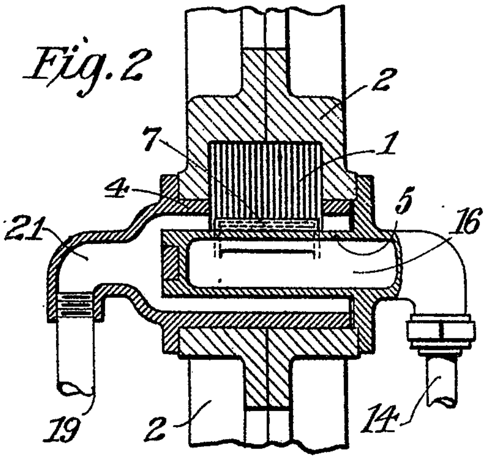


Fig. 2



N° 20,981 A.D. 1896

Date of Application, 22nd Sept., 1896—Accepted, 21st Nov., 1896

COMPLETE SPECIFICATION.

[Communicated from abroad by Nikola Tesla, of 46 East Houston Street, New York, United States of America, Electrician.]

Improvements relating to the Production, Regulation, and Utilization of Electric Currents of High Frequency, and to Apparatus therefor.

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention, subject of the present application, is embodied in certain improvements in methods of and apparatus for producing, regulating and utilizing electric currents of high frequency heretofore invented by Nikola Tesla, and described in British Letters Patent No. 8575, dated May 19, 1891. The method and apparatus referred to in said patent were devised for the purpose of converting, supplying and utilizing electrical energy in a form suited for the production of certain novel electrical phenomena which require currents of high potential and a higher frequency than can readily or even possibly, be developed by generators of the ordinary types or by such mechanical appliances as were theretofore known. The invention referred to was based upon the principle of charging a condenser or a circuit possessing capacity and discharging the same, generally through the primary of a transformer, the secondary of which constituted the source of working current, and under such conditions as to yield a vibratory or rapidly intermittent discharge current.

The present invention, while aiming to simplify and render more efficient the apparatus heretofore used, has for its object, primarily, to provide a means for converting such currents as are generally and most readily obtainable from the mains of ordinary systems of municipal distribution, into currents of the special character referred to, and to regulate or control, and utilize such currents in a simple, economical and efficient manner. The improvements are illustrated herein in forms of apparatus adapted for use with existing circuits or systems, and which while constructed and operating on the same general principles are modified only as may be required by a direct or an alternating source of supply.

The apparatus by which the present improvements are carried out may be described in general terms as comprising a circuit from a given source of supply, in which is included or with which is connected any suitable device for making and breaking such circuit in the manner desired, a condenser arranged so as to be periodically charged by the said circuit through the instrumentality of the circuit controller, and a circuit, through which the condenser discharges, of such character that the discharge will take place in a series of rapidly recurring or intermittent impulses.

In the drawings which illustrate the invention,

Fig. 1 is a diagram of circuits and apparatus employed with a source of direct currents. Figs. 2 and 3 are modifications of the same.

Figs. 4, 5 and 6 illustrate the apparatus and circuit connections employed with a source of alternating current. Figs. 7, 8, 9, 10 are similar views illustrating the method of and apparatus for regulating the system.

[*Price 8d.*]

Figs. 11, 12, 13, 14 and 15 are views illustrating a form of circuit controller for use with the system and the manner of connecting up and using the same.

When the apparatus is to be employed for the purpose of converting a direct current of comparatively low potential into one of high frequency, a device in the nature of a choking coil is interposed in the circuit, in order that advantage may be taken of the discharge of high electro-motive force, which is manifested at each break of such circuit, for charging a condenser.

It will be apparent from a consideration of the conditions involved, that were the condenser to be directly charged by the current from the source and then discharged into its local or discharging circuit, a very large capacity would ordinarily be required, but by the introduction into the charging circuit of a high self induction the current of high electro-motive force which is induced at each break of said circuit, furnishes the proper current for charging the condenser, which may, therefore, be small and inexpensive.

Figures 1 and 2 illustrate that part of the improvement which relates to the conversion of direct or continuous current. Referring to said figures, A designates any source of direct current. In any branch of the circuit from said source, such, for example, as would be formed by the conductors A^{11} A^{11} from the mains A^1 A^1, and the conductors K K are placed self induction or choking coils B B and any proper form of circuit controlling device as C. This device in the present instance is shown as an ordinary metallic disk or cylinder with teeth or separated segments D D, E E, of which one or more pairs as E E, diametrically opposite, are integral or in electrical contact with the body of the cylinder, so that when the controller is in the position in which the two brushes F, F^1, bear upon two of said segments E E, the circuit through the choking coils B B will be closed. The segments D, D, are insulated, and while shown in the drawings as of substantially the same length of arc as the segments E E, this latter relation may be varied at will to regulate the periods of charging and discharging.

The controller is designed to be rotated by any proper device, such for example, as an electro-magnetic motor, as shown in Figure 2, receiving current either from the main source or elsewhere.

Around the controller C or in general having its terminals connected with the circuit on opposite sides of the point of interruption, is a condenser H, or a circuit of suitable capacity, and in series with the latter the primary K of a transformer, the secondary L of which constitutes the source of the currents of high frequency. L^1 indicates the circuit from the secondary and may be regarded as the working circuit.

It will be observed that since the self induction of the circuit through which the condenser discharges, as well as the capacity of the condenser itself, may be given practically any desired value, the frequency of the discharge current may be adjusted at will.

In the operation of this apparatus the controller closes the charging circuit and then interrupts the same. When the break occurs the accumulated energy in the said circuit charges the condenser. Then while the charging circuit is again completed the condenser discharges through the primary K, by a succession of rapid impulses. These operations are maintained by the action of the controller.

A more convenient and simplified arrangement of the apparatus is shown in Figure 2. In this case the small motor G which drives the controller has its field coils M M^1 in derivation to the main circuit, and the controller C and condenser H, are in parallel in the field circuit between the two coils. In such case the field coils M M^1 take the place of the choking coils B.

In this arrangement, and in fact, generally, it is preferable to use two condensers or a condenser in two parts, and to arrange the primary coil of the transformer between them. The interruption of the field circuit of the motor should be so rapid as to permit only a partial demagnetization of the cores; these latter, moreover, should in this specific arrangement, be laminated.

In lieu of connecting the field coils of the motor only with the charging circuit to raise the self induction therein, the motor may be connected in other ways, that is to say, its armature only may be connected with the circuit, or its field and armature coils may be in series and both connected with such circuit. This latter arrangement is illustrated in Figure 3, in which a terminal of the circuit A^{11} is connected to one of the binding posts of the motor from which the circuit is led through one field coil M, the brushes and commutator C^1 and the other field coil M^1, and thence to a brush F which rests upon the controller disk or cylinder C. The other terminal of the circuit connects with a second brush F^1 bearing on the controller, so that the current which passes through and operates the motor is periodically interrupted.

As an illustration of the various uses to which the apparatus may be put, the secondary L^1 is shown in this figure as connected to two plates P, P, of any suitable character between which a current of air is maintained by a fan on the shaft of the motor G, for developing ozone or for similar purposes.

When the potential of the source of current periodically rises and falls, whether with reversals or not is immaterial, it is essential to economical operation that the intervals of interruption of the charging circuit should bear a definite time relation to the period of the current, in order that the effective potential of the impulses charging the condenser may be as high as possible. In case, therefore, an alternating or equivalent electromotive force be employed as the source of supply, a circuit controller is used which will interrupt the charging circuit at instants predetermined with reference to the variations of potential therein.

A convenient, and probably the most practicable means for accomplishing this is a synchronous motor connected with the source of supply and operating a circuit controller which first interrupts the charging current at or about the instant of highest intensity of each wave and then permits the condenser to discharge the energy stored in it, through its appropriate circuit. Such apparatus, which may be regarded as typical of the means for accomplishing this purpose, is illustrated in Figures 4, 5 and 6.

In Fig. 4, A^{11} A^{11} are the conductors taken from the mains of any alternating current generator A, and for raising the potential of such current a transformer is employed represented by the primary B and secondary B^1.

The circuit of the secondary includes the energizing coils of a synchronous motor G, and a circuit controller C fixed to the shaft of the motor.

An insulating arm O, stationary with respect to the motor shaft and adjustable with reference to the poles of the fixed magnets, carries two brushes F F^1 which bear upon the periphery of the disk C. With the parts thus arranged, the secondary circuit is completed through the coils of the motor whenever the two brushes rest upon the uninsulated segments of the disk, and interrupted through the motor at other times.

Such a motor, if properly constructed, in well understood ways, maintains very exact synchronism with the alternations of the source, and the arm O may, therefore, be adjusted to interrupt the current at any determined point of its waves. By the proper relations of insulated and conducting segments, and the motor poles, the current may be interrupted twice in each complete wave at or about the points of highest intensity.

In order that the energy stored in the motor circuit may be utilized at each break to charge the condenser H, the terminals of the latter are connected to the two brushes F F^1 or to points of the circuit adjacent thereto, so that when the circuit through the motor is interrupted the terminals of the motor circuit will be connected with the condenser. The discharge of the condenser takes place through the primary K, the circuit of which is completed simultaneously with the motor circuit and interrupted while the motor circuit is broken and the condenser being charged. The secondary impulses of high potential and great frequency are available for the operation of vacuum tubes P, single terminal lamps R, and other novel and useful purposes.

It is obvious that the supply current need not be alternating, provided it be converted or transformed into an alternating current, before reaching the controller. For example, the present improvements are applicable to various forms of rotary transformers as is illustrated in Figs. 5 and 6.

G^1 designates a continuous current motor, here represented as having four field poles wound with coils E^{11} in shunt to the armature. The line wires A^{11} A^{11} connect with the brushes *b b* bearing on the usual commutator.

On an extension of the motor shaft is a circuit controller composed of a cylinder, the surface of which is divided into four conducting segments *c*, and four insulating segments *d*, the former being diametrically connected in pairs as shown in Fig. 6.

Through the shaft run two insulated conductors *e e* from any two commutator segments ninety degrees apart, and these connect with the two pairs of segments *c*, respectively. With such arrangement, it is evident that any two adjacent segments *c c* become the terminals of an alternating current source, so that if two brushes F F^1 be applied to the periphery of the cylinder they will take off current during such portion of the wave as the width of segment and position of the brushes may determine. By adjusting the position of the brushes relatively to the cylinder, therefore, the alternating current delivered to the segments *c c* may be interrupted at any point of its waves.

While the brushes F F^1 are on the conducting segments the current which they collect stores energy in a circuit of high self-induction formed by the wires *f f*, self-induction coils S S, the conductors A^{11} A^{11}, the brushes and commutator. When this circuit is interrupted by the brushes F F^1, passing onto the insulating segments of the controller, the high potential discharge of this circuit stores energy in the condensers H H which then discharge through the circuit of low self-induction containing the primary K. The secondary circuit contains any devices as P, R, for utilizing the current.

In some cases the energy delivered by the system may be readily and economically regulated. It is well known that every electric circuit, provided its ohmic resistance does not exceed certain definite limits, has a period of vibration of its own analogous to the period of vibration of a weighted spring. In order to alternately charge a given circuit of this character by periodic impulses impressed upon it and to discharge it most effectively, the frequency of the impressed impulses should bear a definite relation to the frequency of vibration possessed by the circuit itself. Moreover, for like reasons, the period of vibration of the discharge circuit should bear a similar relation to the impressed impulses or the period of the charging circuit. When the conditions are such that the general law of harmonic vibrations is followed, the circuits are said to be in resonance or in electro-magnetic synchronism, and this condition of the system is found to be highly advantageous.

In carrying out the invention, therefore, the electrical constants should be so adjusted that in normal operation the condition of resonance is approximately attained. To accomplish this, the number of impulses of current directed into the charging circuit per unit time is made equal to the period of the charging circuit itself, or, generally, to a harmonic thereof, and the same relations are maintained between the charging and discharge circuit. Any departure from this condition will result in a decreased output, and this fact is taken advantage of in regulating such output by varying the frequencies of the impulses or vibrations in the several circuits.

Inasmuch as the period of any given circuit depends upon the relations of its resistance, self-induction and capacity, a variation of any one or more of these may result in a variation in its period. There are, therefore, various ways in which the frequencies of vibration of the several circuits in the system may be varied, but the most practicable and efficient ways of accomplishing the desired result are the following:

(*a*) Varying the rate of the impressed impulses or those which are directed from the source of supply into the charging circuit, as by varying the speed of the commutator or other circuit controller.

(*b*) Varying the self-induction of the charging circuit.

(*c*) Varying the self-induction or capacity of the discharge circuit.

To regulate the output of a single circuit which has no vibration of its own, by merely varying its period would evidently require, for any extended range of regulation, a very wide range of variation of period. But in the system described, a very wide range of regulation of the output may be obtained by a very slight change of the frequency of one of the circuits when the above mentioned rules are observed.

Figs. 7, 8, 9 and 10 illustrate some of the more practicable means for effecting the regulation, as applied to a system deriving its energy from a source of direct currents.

In each of the figures A^{11} A^{11} designate the conductors of a supply circuit of continuous current, G a motor connected therewith in any of the usual ways, and operating a current controller C which serves to alternately close the supply circuit through the motor or through a self-induction coil, and to connect such motor circuit with a condenser H, the circuit of which contains a primary coil K, in proximity to which is a secondary coil L serving as the source of supply to the working circuit or that in which are connected up the devices P R for utilizing the current.

In order to secure the greatest efficiency in a system of this kind, it is essential, as before stated, that the circuits, which mainly as a matter of convenience are designated as the charging and the discharge circuits, should be approximately in resonance or electro-magnetic synchronism. Moreover, in order to obtain the greatest output from a given apparatus of this kind it is desirable to maintain as high a frequency as possible.

The electrical conditions, which are now well understood, having been adjusted to secure, as far as practical considerations will permit, these results, the regulation of the system is effected by adjusting its elements so as to depart in a greater or less degree from the above conditions with a corresponding variation of output. For example, as in Figure 7 the speed of the motor, and consequently of the controller, may be varied in any suitable manner, as by means of a rheostat R^1 in a shunt to such motor, or by shifting the position of the brushes on the main commutator of the motor or otherwise. A very slight variation in this respect by disturbing the relations between the rate of impressed impulses and the vibration of the circuit of high self-induction into which they are directed, causes a marked departure from the condition of resonance and a corresponding reduction in the amount of energy delivered by the impressed impulses to the apparatus.

A similar result may be secured by modifying any of the constants of the local circuits as above indicated. For example, in Figure 8 the choking coil B is shown as provided with an adjustable core N^1, by the movement of which into and out of the coil the self-induction, and consequently the period of the circuit containing such coil, may be varied.

As an example of the way in which the discharge circuit or that into which the condenser discharges, may be modified to produce the same result, there is shown in Figure 9 an adjustable self-induction coil R^{11} in the circuit with the condenser, by the adjustment of which coil the period of vibration of such circuit may be changed.

The same result would be secured by varying the capacity of the condenser, but if the condenser were of relatively large capacity this might be an objectionable plan, and a more practicable method is to employ a variable condenser in the secondary or working circuit, as shown in Figure 10. As the potential in this circuit is raised to a high degree, a condenser of very small capacity may be employed, and if the two circuits, primary and secondary, are very intimately and closely connected, the variation of capacity in the secondary is similar in its effects to the variation of the capacity of the condenser in the primary. As a means well adapted for this purpose two metallic plates S^1 S^1 adjustable to and from each other and constituting the two armatures of the condenser are shown.

The description of the means of regulation is confined herein to a source of supply of direct current, for to such it more particularly applies, but it will be understood that if the system be supplied by periodic impulses from any source which will effect the same results, the regulation of the system may be effected by the method herein described.

The circuit controller or the device which ensures the proper charging and discharging of the condenser may be of any construction that will perform the functions required of it. In illustration of the principle of construction and mode of operation, reference has been made only to forms of mechanism that make and break metallic contacts, but there need be no actual metallic contact, if provision be made for the passage of a spark between separated conductors. Such a device is illustrated in Figs. 11 to 15.

A designates, in Fig. 11, a generator having a commutator a^1 and brushes a^{11} bearing thereon, and also collecting rings b^{11}, b^{11}, from which an alternating current is taken by brushes b^1 in the well understood manner.

The circuit controller is mounted, in part, on an extension of the shaft c^1 of the generator, and in part on the frame of the same, or on a stationary sleeve surrounding the shaft. Its construction, in detail, is as follows:—

e^1 is a metal plate with a central hub e^{11} which is keyed or clamped to the shaft c^1. The plate is formed with segmental extensions corresponding in number to the waves of current which the generator delivers. These segments are preferably cut away, leaving only rims or frames, to one of the radial sides of which are secured bent metal plates i which serve as vanes to maintain a circulation of air when the device is in operation.

The segmental disk and vanes are contained within a close insulated box or case f mounted on the bearing of the generator, or in any other proper way, but so as to be capable of angular adjustment around the shaft. To facilitate such adjustment, a screw rod f^1, provided with a knob or handle, is shown as passing through the wall of the box. The latter may be adjusted by this rod, and when in proper position may be held therein by screwing the rod down into a depression in the sleeve or bearing as shown in Fig. 11.

Air passages g g are provided at opposite ends of the box through which air is maintained in circulation by the action of the vanes.

Through the sides of the box f, and through insulating gaskets h, when the material of the box is not a sufficiently good insulator, extend metallic terminal plugs l, l, with their ends in the plane of the conducting segmental disk e^1 and adjustable radially towards and from the edges of the segments.

Devices of this character are employed in the manner illustrated in Fig. 13.

A, in this figure, represents any source of alternating current, the potential of which is raised by a transformer of which B is the primary and B^1 the secondary.

The ends of the secondary circuit s are connected to the terminal plugs l, l, of an apparatus similar to that of Figures 11 and 12, and having segments rotating in synchronism with the alternations of the current source, preferably, as above described, by being mounted on the shaft of the generator, when the conditions so permit.

The plugs l, l, are then adjusted radially so as to approach more or less the path of the outer edges of the segmental disk, and so that during the passage of each segment in front of a plug a spark will pass between them, which completes the secondary circuit, s. The box, or the support for the plugs l, is adjusted angularly so as to bring the plugs and segments into proximity at the desired instants with reference to any phase of the current wave in the secondary circuit, and fixed in position in any proper manner.

To the plugs l, l, are also connected the terminals of a condenser or condensers, so that at the instant of the rupture of the secondary circuit s by the cessation of the sparks the energy accumulated in such circuit will rush into, and charge, the condenser.

A path of low self-induction and resistance, including a primary K of a few turns, is provided to receive the discharge of the condenser, when the circuit *s* is again completed by the passage of sparks, the discharge being manifested as a succession of extremely rapid impulses.

By means of this apparatus effects of a novel and useful character are obtainable, but to still further increase the efficiency of the discharge or working current, there may be in some instances provided a means for further breaking up the individual sparks themselves. A device for this purpose is shown in Figures 14 and 15.

The box or case *f* in these figures is fixedly secured to the frame or bearing of the generator or motor which rotates the circuit controller in synchronism with the alternating source. Within said box is a disk e^1 fixed to the shaft c^1 with projections d^1 extending from its edge parallel with the axis of the shaft. A similar disk e^1 on a spindle d^{11} in face of the first is mounted in a bearing in the end of the box *f* with a capability of rotary adjustment.

The ends of the projections d^1 are deeply serrated or several pins or narrow projections placed side by side, as shown in Fig. 14, so that as those of the opposite disks pass each other a rapid succession of sparks will pass from the projections of one disk to those of the other.

The invention is not limited to the precise devices or forms of the devices shown and described. For example, when the source of supply is a circuit of high self-induction no special choking coils or the like need be employed. So, too, the condenser as a distinctive apparatus may be dispensed with when the capacity of its circuit is sufficiently great to accomplish the desired result. The circuit controller may, as already explained, be very greatly modified and varied in construction and principle of operation without departure from the invention.

In the illustrations given of the circuit controller, the contacts and insulating spaces are arranged for charging and discharging a single condenser, but it is obvious that a single motor and circuit controller may be used to operate more than one condenser, by charging one while discharging the other or others.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. The apparatus herein described for converting electric currents of the kind generally obtainable from municipal systems of electric distribution, into currents of high frequency, comprising in combination a circuit of high self-induction, a circuit controller adapted to make and break such circuit, a condenser into which the said circuit discharges when interrupted, and a transformer through the primary of which the condenser discharges, as set forth.

2. The combination with a circuit of high self-induction and means for making and breaking the same, of a condenser around the point of interruption in the said circuit, and a transformer the primary of which is in the condenser circuit, as described.

3. The combination with a circuit having a high self-induction, of a circuit controller for making and breaking said circuit, a motor for driving the controller, a condenser in a circuit connected with the first around the point of interruption therein, and a transformer the primary of which is in circuit with the condenser, as set forth.

4. The combination with an electric circuit of a controller for making and breaking the same, a motor included in or connected with said circuit so as to increase its self-induction and driving the said controller, a condenser in a circuit around the controller, and a transformer through the primary of which the condenser discharges, as set forth.

5. The combination with a circuit of direct current, of a controller for making and breaking the same, a motor having its field or armature coils or both included in said circuit and driving said controller, a condenser connected

with the circuit around the point of interruption therein, and a transformer, the primary of which is in the discharge circuit of the condenser, as set forth.

6. The method herein described of converting alternating currents of relatively low frequency into currents of high frequency, which consists in charging a condenser by such currents of low frequency during determinate intervals of each wave of said current, and discharging the condenser through a circuit of such character as to produce therein a rapid succession of impulses, as set forth.

7. The combination with a source of alternating current, a condenser, a circuit controller adapted to direct the current during determinate intervals of each wave into the condenser for charging the same, and a circuit into which the condenser discharges, as set forth.

8. The combination with a source of alternating current, a synchronous motor operated thereby, a circuit controller operated by the motor and adapted to interrupt the circuit through the motor at determinate points in each wave, a condenser connected with the motor circuit and adapted on the interruption of the same to receive the energy stored therein, and a circuit into which the condenser discharges, as set forth.

9. The combination with a source of alternating current, a charging circuit in which the energy of said current is stored, a circuit controller adapted to interrupt the charging circuit at determinate points in each wave, a condenser for receiving, on the interruption of the charging circuit, the energy accumulated therein, and a circuit into which the condenser discharges when connected therewith by the circuit controller, as set forth.

10. The method of regulating the energy delivered by a system for the production of high frequency currents, and comprising a supply circuit, a condenser, a circuit through which the same discharges, and means for controlling the charging of the condenser by the supply circuit and the discharging of the same, the said method consisting in varying the relations of the frequencies of the impulses in the circuits comprising the system, as set forth.

11. The method of regulating the energy delivered by a system for the production of high frequency currents comprising a supply circuit of direct currents, a condenser adapted to be charged by the supply circuit and to discharge through another circuit, the said method consisting in varying the frequency of the impulses of current from the supply circuit, as set forth.

12. The method of producing and regulating electric currents of high frequency which consists in directing impulses from a supply circuit into a charging circuit of high self-induction, charging a condenser by the accumulated energy of such charging circuit, discharging the condenser through a circuit of low self-induction, raising the potential of the condenser discharge and varying the relations of the frequencies of the electrical impulses in the said circuits, as set forth.

13. The combination with a source of current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit controller for effecting the charging and discharge of said condenser, composed of conductors movable into and out of proximity with each other, whereby a spark may be maintained between them and the circuit closed thereby during determined intervals, as set forth.

14. The combination with a source of alternating current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit controller for effecting the charging and discharge of said condenser composed of conductors movable into and out of proximity with each other in synchronism with the alternations of the source, as set forth.

15. A circuit controller for systems of the kind described, comprising in combination a pair of angularly adjustable terminals and two or more rotating conductors mounted to pass in proximity to the said terminals, as set forth.

16. A circuit controller for systems of the kind described, comprising in

combination two sets of conductors, one capable of rotation and the other of angular adjustment whereby they may be brought into and out of proximity to each other at determinate points and one or both being subdivided so as to present a group of conducting points, as set forth.

Dated this 22nd day of September 1896.

HASELTINE, LAKE & Co.,
45 Southampton Buildings, London, W.C., Agents for the Applicant.

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Fig. 1

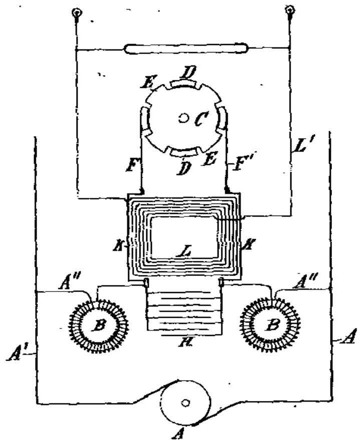

Fig. 2

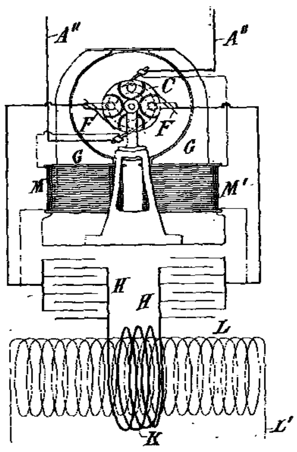

Fig. 3

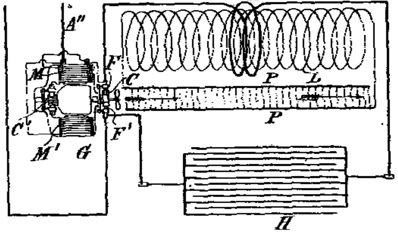

Fig. 9

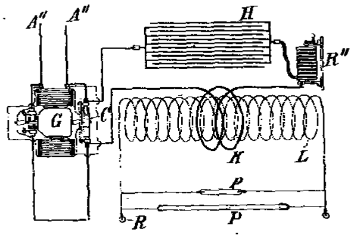

Fig. 7

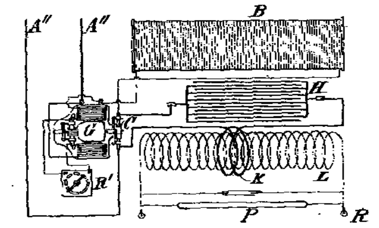

Fig. 8

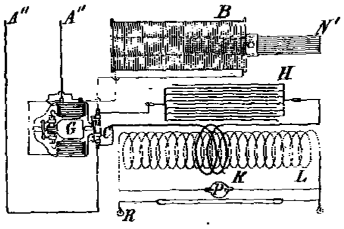

Fig. 10

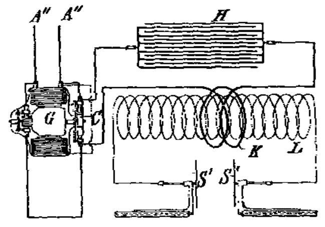

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Fig. 1

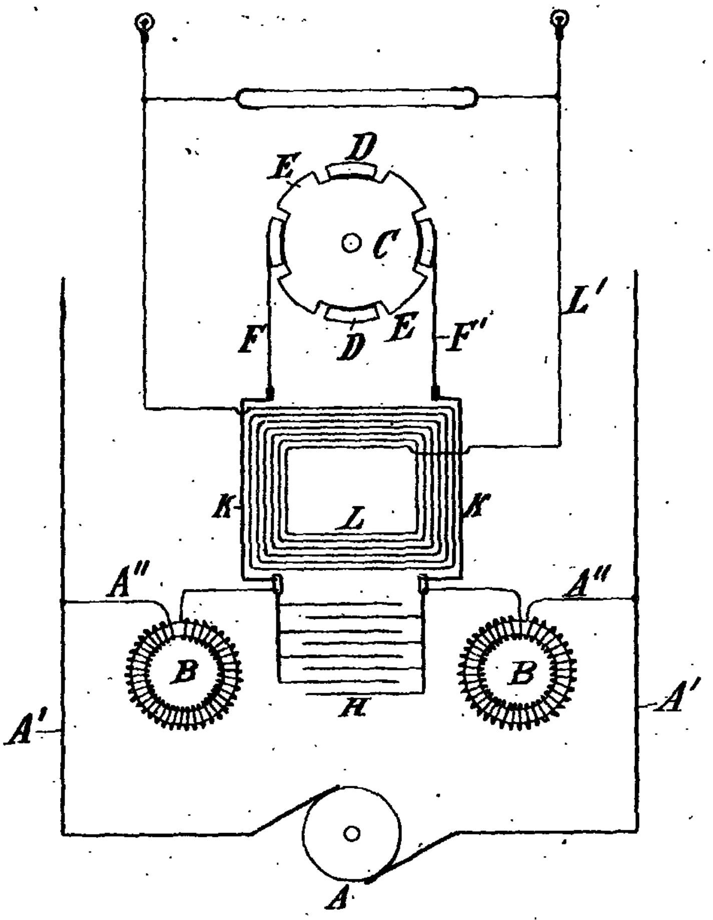


Fig. 2

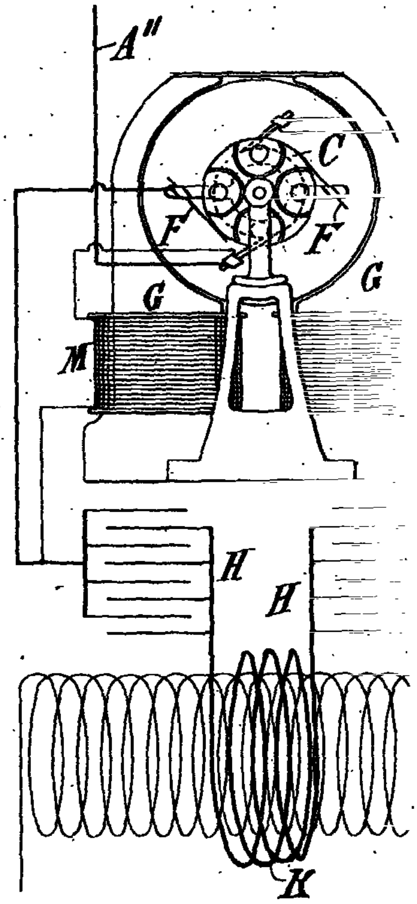


Fig. 7

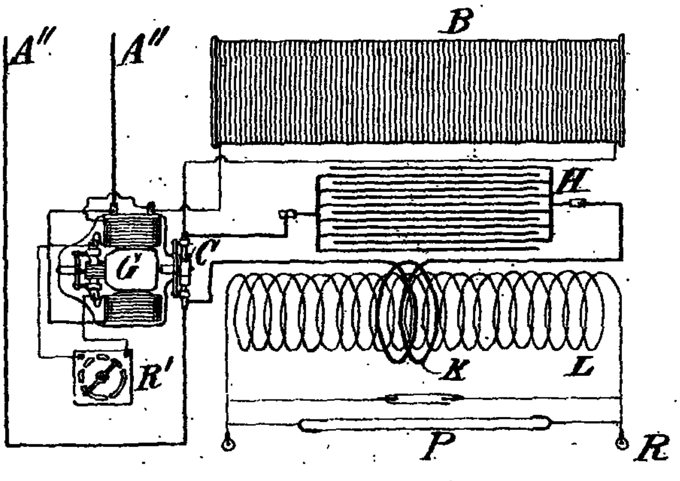
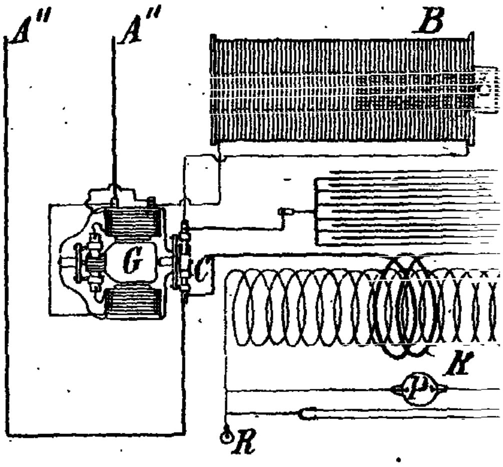


Fig. 8



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SHEET 1.

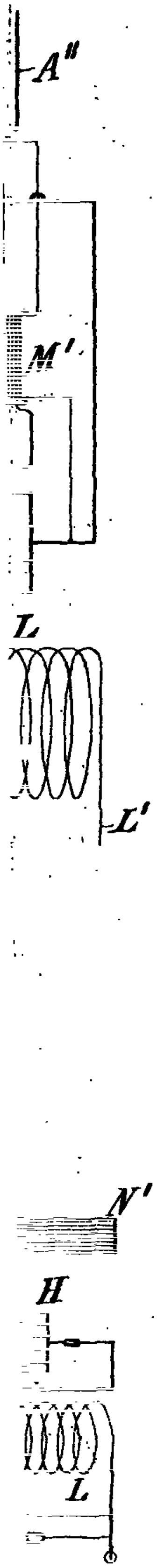

Fig. 3

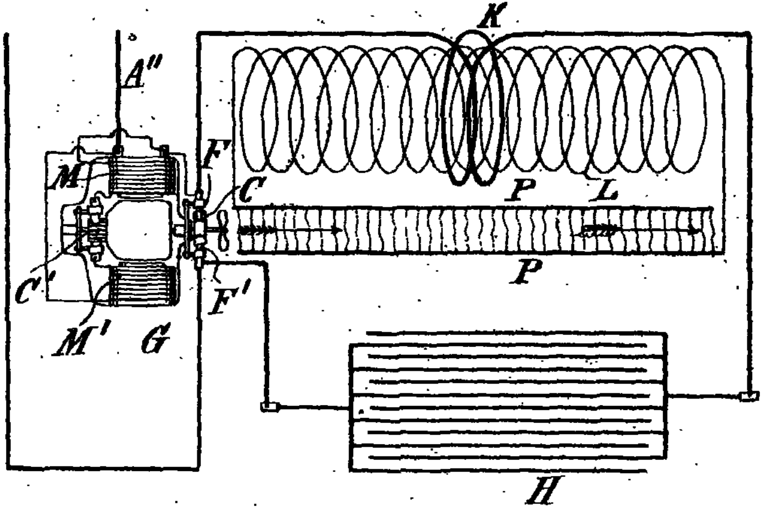

Fig. 9

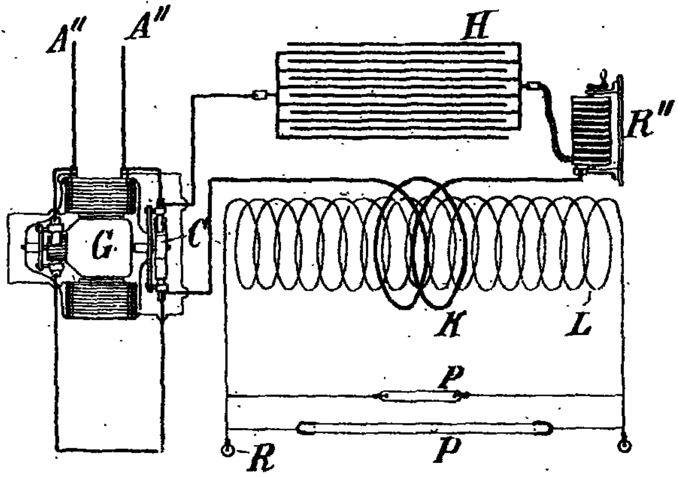

Fig. 10

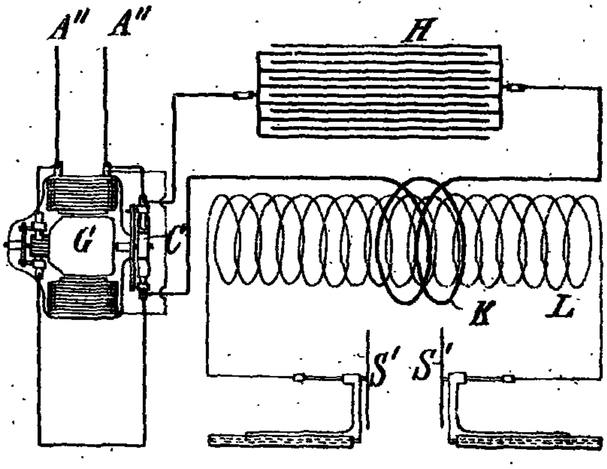

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Fig. 4

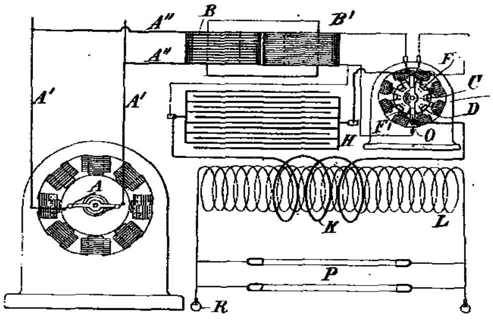

Fig. 5

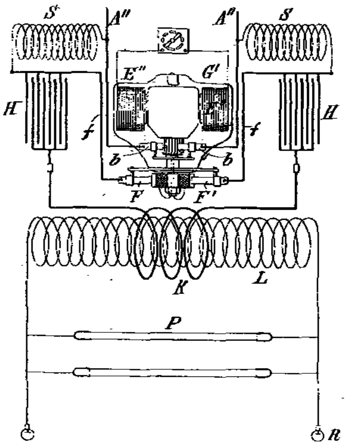

Fig. 6

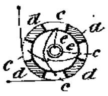

Fig. 11

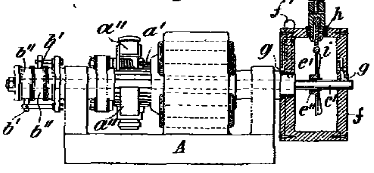

Fig. 12

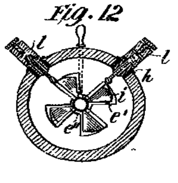

Fig. 13

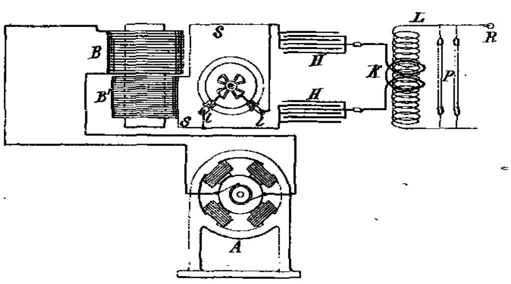

Fig. 14

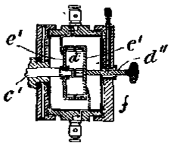

Fig. 15

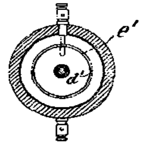

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Fig. 4

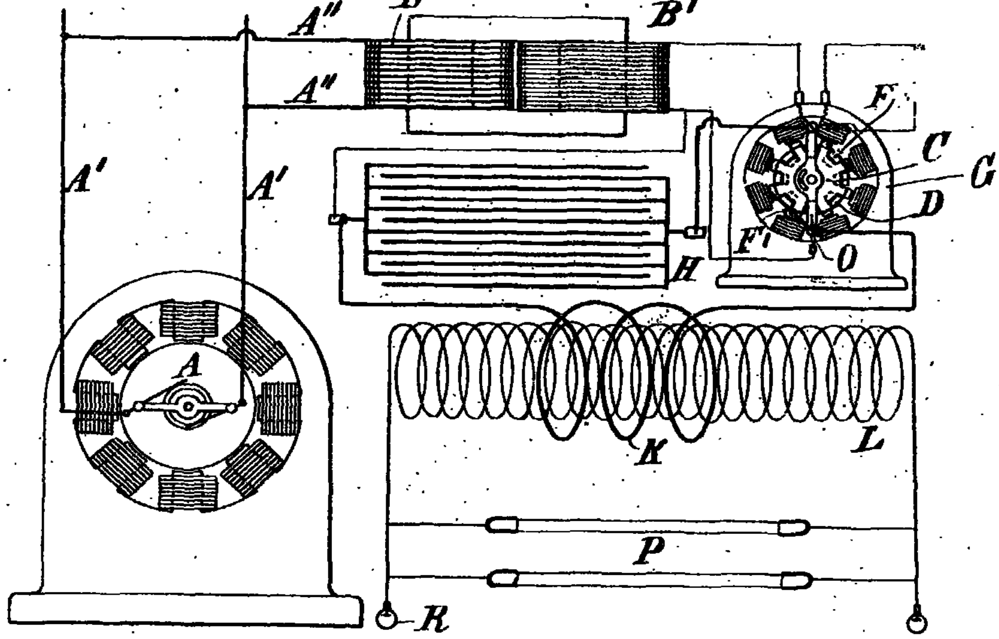


Fig.

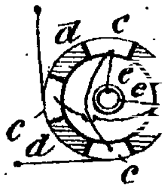


Fig. 11

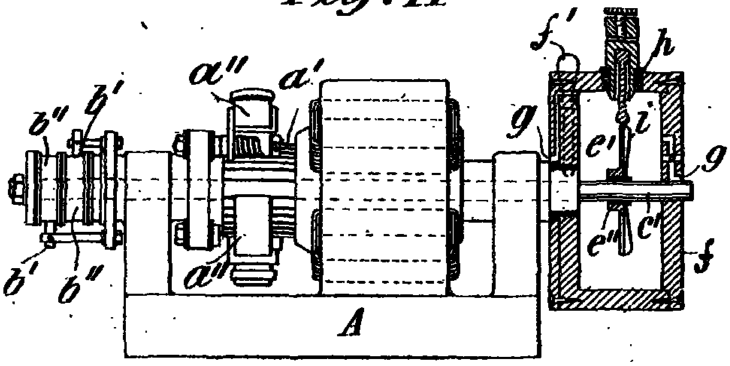


Fig. 12

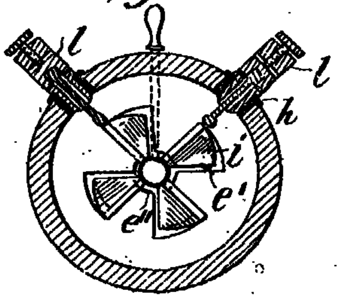


Fig. 14

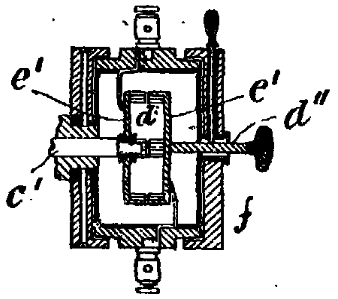
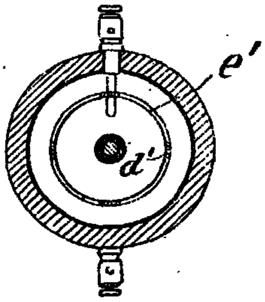


Fig. 15



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SHEET 2.

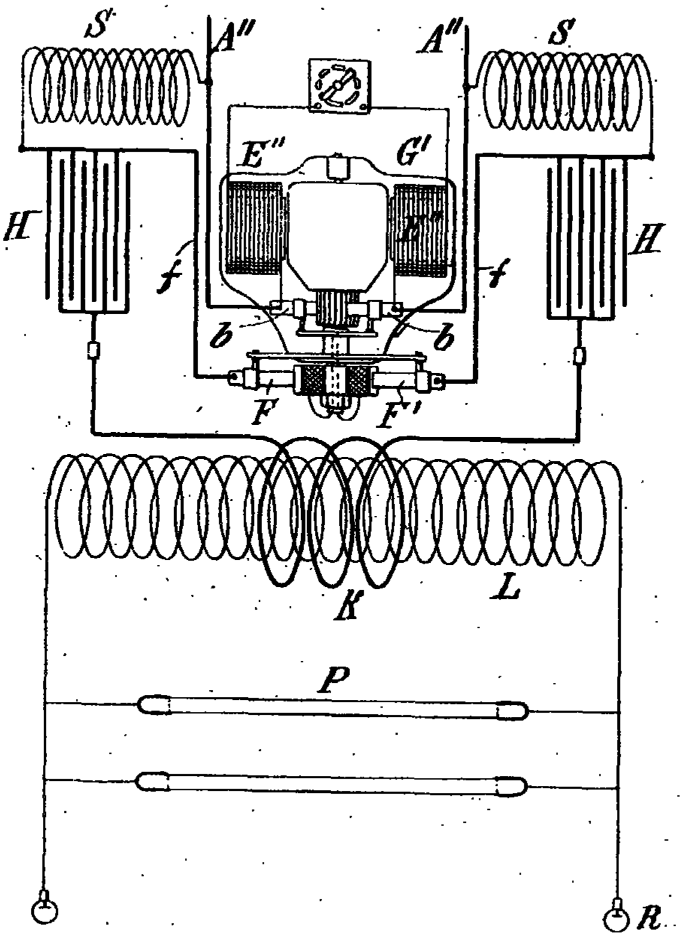

Fig. 5

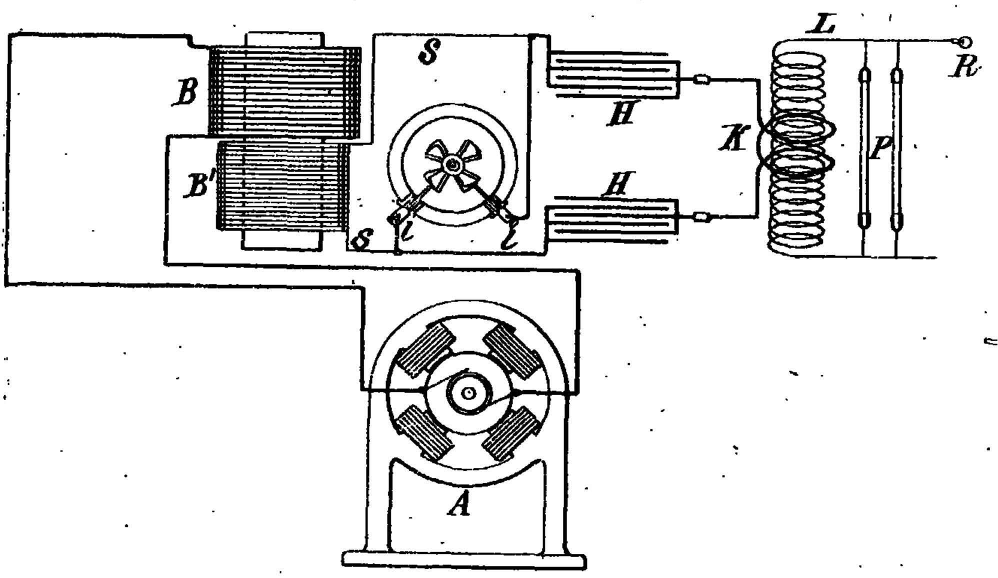

Fig. 13

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N° 24,421 A.D. 1897

Date of Application, 21st Oct., 1897—Accepted, 26th Mar., 1898

COMPLETE SPECIFICATION.

[Communicated from abroad by Nikola Tesla, of New York, in the County and State of New York, United States of America, Electrician.]

Improvements in Systems for the Transmission of Electrical Energy and Apparatus for use therein.

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45, Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

It has been well known, hertofore, that if the air enclosed in a vessel be rarefied, its insulating properties are impaired to such extent that it becomes what may be considered as a true conductor of electricity, although one of admittedly high resistance. The practical information in this matter, however, has been derived from observations manifestly subject to limitations imposed by the character of the apparatus or means heretofore known, and the quality of the electrical effects producible thereby.

It has also been known, particularly since the investigations of Heinrich Herz, that certain transverse electrical waves or radiations may be transmitted through the atmosphere, and these have been found capable of affecting certain delicate receiving instruments at a limited distance from the source of the electrical disturbance.

The invention which forms the subject of the present application comprises a novel method or system for the transmission of electrical energy without the employment of metallic line conductors, and is primarily designed for use in cases where large amounts of electrical energy are to be transmitted to considerable distances, but the results arrived at are of such character and magnitude, as compared with any heretofore secured, as to render indispensable the employment of means and the utilization of effects essentially different in their characteristics and actions from those before used or investigated.

To be more explicit, the transmission of electrical energy, which forms a part of my present invention, demands for the attainment of practically useful results, the production and conversion of excessively high electrical pressures. Heretofore, it has been possible, by means of the apparatus at command, to produce only moderate effective electrical pressures, and even these not without some risks and difficulties, but I have devised means whereby I am enabled to generate with safety and ease electrical pressures measured by hundreds of thousands, and even millions, of volts, and in pursuing investigations with such apparatus I have discovered certain highly important and useful facts which render practicable the method of transmission of electrical energy hereinafter described.

Among these, and bearing directly upon the invention, are the following; First, that with electrical pressures of the magnitude and character which I have made it possible to produce, the ordinary atmosphere becomes, in a measure, capable of serving as a true conductor for the transmission of the current. Second, that the conductivity of the air increases so materially with the increase of elec-

[*Price* 8*d*.]

trical pressure and degree of rarefaction, that it becomes possible to transmit through even moderately rarefied strata of the atmosphere, electrical energy up to practically any amount and to any distance.

The system of transmission comprised in my present invention and which, as above stated, was rendered possible only by the production of apparatus of a character radically new and different from any before known, and which is based upon discoveries made in the investigation of the results produced thereby, consists then in producing at a given point a very high electrical pressure, conducting the current caused thereby to earth and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first.

In order to attain this result it is necessary to employ an apparatus capable of generating electrical pressures vastly in excess of any heretofore used, and to lead the current to earth and to a terminal maintained at an elevation where the rarefied atmosphere is capable of conducting freely the particular current produced; then, at a distant point, where the energy is to be utilized, to maintain a terminal at or about the same elevation to receive the current and to convey it to earth through suitable means for transforming and utilizing it.

The apparatus which I have invented, and by means of which this method of transmission may be effected, is represented in the accompanying drawing, which is a diagrammatic illustration of the system that is to say, each transformer is shown as comprised of a spiral conductor in fine lines surrounded by a conductor in heavy lines with a very few convolutions.

The transformers, as actually constructed are, in reality, nothing more than this. For example, starting on a spool or roll of hard rubber which may contain a central core of iron wires or strands, an insulated wire is wound until a coil is built up of the desired length. This coil is built up precisely as any other, the wire being wound around the core or spool until its convolutions fill up the space and form one complete layer. The winding is continued in the same way until another layer is formed and so on.

When the desired length of secondary or high tension coil is thus obtained, the primary or low tension coil is wound outside of it, but this latter coil is composed of only a very few turns of wire or conductor, which is of much larger diameter or cross-section than the secondary wire.

The transformer thus consists simply of two concentric coils, the inner coil having very many turns of fine wire, the outer coil a very few turns of coarse wire.

From this plan of construction it follows that one of the high tension terminals is at the centre of secondary coil, and in the use of the coil the other terminal whether it be connected to ground or not is electrically connected to the primary in order that there may be no material difference of potential between the latter and the adjacent convolutions of the secondary.

Assuming that it appears from the above that in the general plan of construction of the coils, only common and well known methods have been pursued, it remains then, to consider the length of the secondary coil. This should be approximately one quarter of the wave length of the electrical disturbance in the circuit, and the reason for it is that the highest possible electrical pressures may be secured at the centre terminals of the secondary coils.

A is a coil, generally of many turns and of very large diameter, wound in spiral form either about a magnetic core or not, as may be desired. C is a second coil formed by a conductor of much larger size and smaller length wound around in proximity to the coil A.

In the transmitting apparatus the coil A constitutes the high tension secondary, and the coil C the primary of much lower tension of a transformer. In the circuit of the primary C is included a suitable source of current G.

One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D preferably of large surface formed of or maintained by such means as a balloon at an elevation suitable for the purposes of transmission as before described. The other terminal of the secondary A is connected to earth and, preferably, to the primary also, in order that the latter may be approximately of the same potential as the adjacent portions of the secondary, thus insuring safety.

At the receiving station a transformer of similar construction is employed, but in this case the long coil A^1 constitutes the primary and the short coil C^1 the secondary of the transformer. In the circuit of the latter are arranged lamps L, motors M, or other devices for utilizing the current. The elevated terminal D^1 connects with the center of the coil A^1, and the other terminal of said coil is connected to earth and preferably also to the coil C^1 for the reasons above stated.

The length of the high tension coil of each apparatus should be approximately one-quarter of the wave length of the electrical disturbance in the circuit, this estimate being based on the velocity of propagation of the electrical disturbance through the coil itself and the circuit with which it is designed to be used. To illustrate, in accordance with accepted views, if the rate at which a current traverses the circuit, including the two high tension coils, be 185,000 miles per second, then a frequency of 925 per second would maintain 925 stationary waves in a circuit 185,000 miles long, and each wave would be 200 miles in length. For such a *frequency I should use in each high tension coil a conductor 50 miles in length*, or in general, with due allowance for the capacity of the leading wires and terminals, such length of conductor as would secure the highest electrical pressures at the terminals under the working conditions.

It will be observed that in coils of the character described, the potential gradually increases with the number of turns and the difference of potential between adjacent turns is comparatively small, and a very high potential, impracticable with ordinary coils, may be successfully obtained.

As the main object of the invention is to produce a current of extremely high potential, this object will be facilitated by using a primary current of very considerable frequency, but the frequency of the current is, in large measure, arbitrary, for if the potential be sufficiently high and the terminals of the coils be maintained at a proper elevation there the atmosphere is comparatively rarefied, the intermediate stratum of air will serve as a conductor for the current produced, and the latter will be transmitted through the air with, it may be, even less resistance than through an ordinary copper wire.

The apparatus described, it may be observed, is useful as a means for producing currents of very high potential for other purposes than that of the present system, as, for instance, the coils may be used singly for producing extremely high electrical potentials for any purpose, or used generally in the same manner as other electrical transformers, for the conversion and transmission of electrical energy.

It will be understood that either or both of the coils or transformers and terminals may be movable, as, for instance, when carried by vessels floating in the air, or by ships at sea. In the former case the connection of one terminal with the ground might not be permanent, but might be intermittently or inductively established without departing from the spirit of the invention.

As to the elevation of the terminals D, D^1, it is obvious that this is a matter which will be determined not only by the condition of the atmosphere but also by the character of the surrounding country.

Thus, if there be high mountains in the vicinity, the terminals should be at a greater height, and, generally, they should always be at an altitude much greater than that of the highest objects near them in order to reduce the loss by leakage. Since, by the means described, practically any potential that is desired may be produced, the currents through the air strata may be very small, thus reducing the loss in the air.

It will be observed that the phenomenon here involved in the transmission of electrical energy is one of true conduction, and is not to be confounded with the phenomena of induction or of electrical radiation which have heretofore been observed and experimented with, and which, from their very nature and mode of propagation, would render practically impossible the transmission of any considerable amount of energy to such distances as would be of practical importance.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, as communicated to me by my *foreign correspondent*, I declare that what I claim is:—

1. The method of transmitting electrical energy herein described, which consists in producing at a given point a very high electrical pressure, conducting the current caused thereby to earth and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first, as set forth.
2. A system for the transmission of electrical energy comprising in combination a source of current of very high pressure, connected respectively with earth and with a terminal at an elevation where the atmosphere forms a conducting path for the current produced, a second elevated terminal at a distance from the first for receiving the current transmitted therefrom and means for utilizing the said current, as set forth.
3. The transformer herein described for developing or converting currents of high potential, comprising a low tension and a high tension coil, one terminal of the high tension coil being electrically connected with the low tension coil and with earth when the transformer is in use, as set forth.
4. The transformer herein described for developing or converting currents of high potential, comprising a low tension coil and a high tension coil wound in the form of a flat spiral, the end of the high tension coil adjacent to the low tension coil being electrically connected therewith and with earth when the transformer is in use.
5. The transformer herein described for developing or converting currents of high potential in which the low tension coil and the high tension coil are wound in the form of a spiral, the coil of high tension being inside of, and surrounded by, the convolutions of the other and having its adjacent terminal electrically connected therewith and with earth when the transformer is in use, as set forth.

Dated this 21st day of October 1897.

HASELTINE, LAKE & Co.,
45, Southampton Buildings, London, W.C., Agents for the Applicant.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1898

A.D. 1897. Oct. 21. N°. 24,421.

LAKE'S COMPLETE SPECIFICATION.

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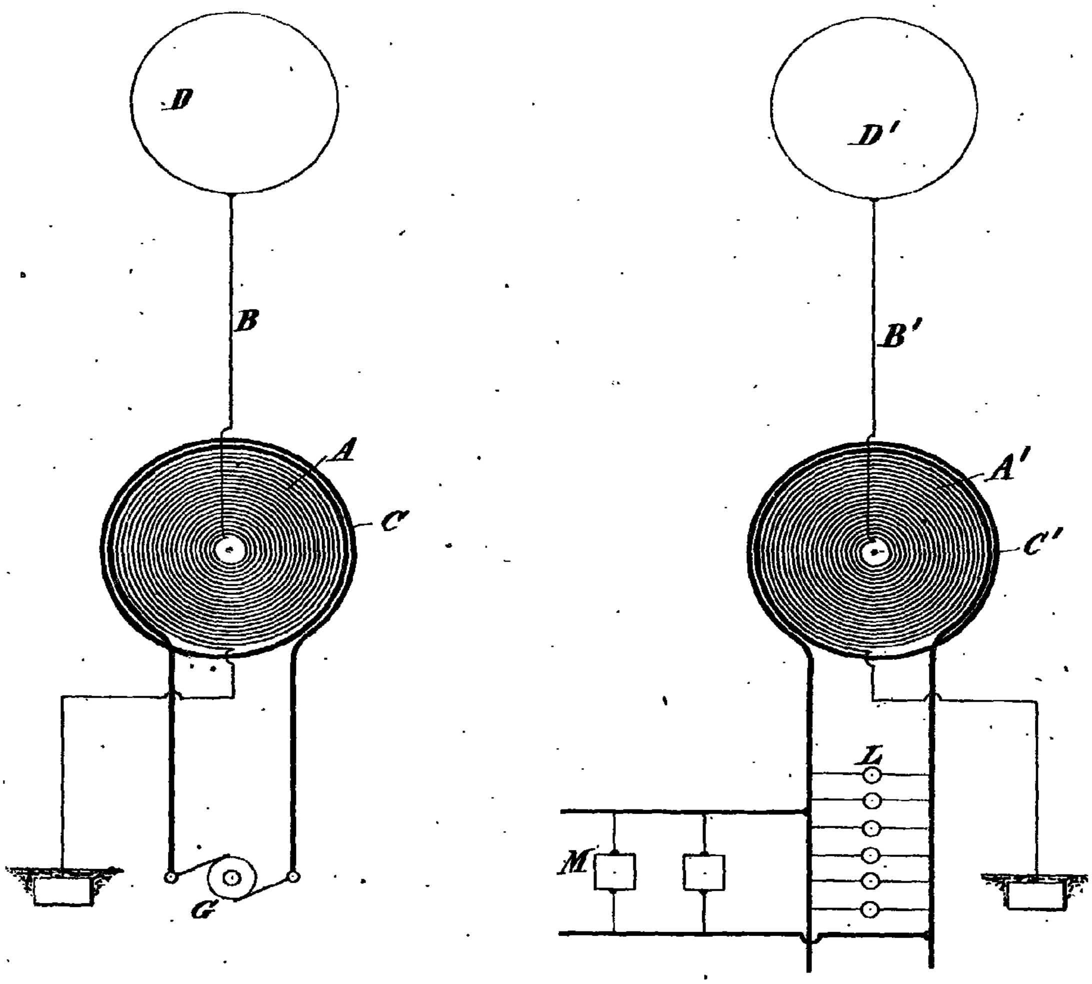

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N° 12,866 A.D. 1898

Date of Application, 8th June, 1898—Accepted, 27th Aug., 1898

COMPLETE SPECIFICATION.

[Communicated from abroad by Nikola Tesla, of 46, East Houston Street, Borough of Manhattan, New York, United States of America, Electrician.]

Improvements in Electrical Circuit Controllers.

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45, Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

I have heretofore invented and patented methods and apparatus for the generation, conversion and utilization of electrical currents of very high frequency based upon the principle of charging a condenser, and discharging the same, generally through the primary of a transformer, the secondary of which constituted the source of working currents, and under such conditions as to yield a vibrating or rapidly intermittent current.

In some of the forms of apparatus which I have heretofore devised for carrying out the methods referred to, I have employed a mechanism for making and breaking an electric circuit or branch thereof for the purpose of charging and discharging the condenser, and the present application is based upon a novel and improved type of a circuit controller or device for this purpose. The principles of construction and operation of the apparatus designed in accordance with this invention will be understood from the following statement of the nature of its requirements and mode of use.

In every device which makes and breaks an electric circuit with any considerable degree of abruptness, a waste of energy occurs during the periods of make or break, or both, due to the passage of the current through an arc formed between the receding or approaching terminals or contacts, or, in general, through a path of high resistance. The tendency of the current to persist after the actual disjunction or to precede the conjunction of the terminals exists in varying degrees in different forms of apparatus, according to the special conditions present. For example, in the case of an ordinary induction coil, the tendency to the formation of an arc at the break is, as a rule, the greater, while in certain forms of apparatus for utilizing the discharge of a condenser, such as heretofore referred to, this tendency is greatest at the instant immediately preceding the conjunction of the contacts of the circuit controller which effects the discharge of the condenser.

The loss of energy occasioned by the causes mentioned may be very considerable, and is generally such as to greatly restrict the use of the circuit controller and render impossible a practical and economical conversion of any considerable amounts of electrical energy by its means, particularly in cases in which a high frequency of the makes and breaks is required.

Extended experiment and investigation, conducted with the aim of discovering a means for avoiding the loss incident to the use of ordinary forms of circuit controllers, have led me to recognize certain laws governing this waste of energy and which show it to be dependent, chiefly, on the velocity with which the terminals approach and recede from one another and also more or less on the form of the current wave. Briefly stated, from both theoretical considerations and practical experiment, it appears that the loss of energy in any device for making and breaking a circuit, other conditions being the same, is inversely proportional rather to the square than to the first power of the speed or relative velocity of the terminals in approaching and receding from one another, in any instance in which the current wave is not so steep as to materially depart from one which may be represented as a sine function of the time.

But such a case seldom obtains in practice; on the contrary, the current curve resulting from a make and break is generally very steep, and particularly so when, as in my system, the circuit controller effects the charging and discharging of a condenser, and consequently the loss of energy is still more rapidly reduced by an increased velocity of approach and separation of the terminals. The demonstration of these facts and the recognition of the impossibility of attaining the desired results by using ordinary forms of circuit controllers, have led me to invent the novel apparatus for making and breaking a circuit, which in several modified forms is made the subject of the present application.

Various devices for making and breaking an electric current have heretofore been used or proposed in which the separable contact points or terminals were contained in an exhausted vessel or surrounded by an inert atmosphere, but there are certain theoretical conditions necessary for complete success, which I have recognized and which have not been attained by the means heretofore employed. These may be summed up as follows:

(1) The medium by which the contact points are surrounded should have as high an insulating quality as possible, so that the terminals may be approached to an extremely short distance before the current leaps across the intervening space.

(2) The closing up or repair of the injured dielectric, or in other words, the restoration of the insulating power, should be instantaneous, in order to reduce to a minimum the time during which the waste principally occurs.

(3) The medium should be chemically inert so as to diminish as much as possible the deterioration of the electrodes and to prevent chemical processes which might result in the development of heat, or in general, in loss of energy.

(4) The giving way of the medium under the application of electrical pressure should not be of a yielding nature, but should be very sudden, and in the nature of a crack, similar to that of a solid, such as a piece of glass, when squeezed in a vice;

(5) And most important, the medium ought to be such that the arc, when formed, is restricted to the smallest possible linear dimensions and is not allowed to spread or expand.

As a step in the direction of these theoretical requirements I have heretofore employed in some of my circuit controlling devices a fluid of high insulating qualities, such as liquid hydro-carbon, and caused the same to be forced, preferably, with great speed, between the approaching and receding contact points of the circuit controller. By the use of such liquid insulation a very marked advantage was secured, but while some of the above requirements were attained in this manner, certain defects still existed, notably that due to the fact that the inslating liquid, in common with a vacuous space, though in a lesser degree, permits the arc to expand in length and thickness, and to thus pass through all degrees of resistance, thereby causing a greater or less waste of energy.

To overcome this defect and to still more nearly attain the theoretical conditions required for most efficient working of the circuit controlling devices, I have been finally led to use a gaseous insulating medium subjected to great pressure.

The application of great pressure to the medium in which the make and break are made, secures a number of special advantages. One of these may be obviously inferred from well-established experimental facts, which demonstrate that the striking distance of an arc is, approximately, inversely proportional to the pressure of the gaseous medium in which it occurs. But in view of the fact that in most cases occurring in practice the striking distance is very small, since the differences of potential between the electrodes are usually not more than a few hundred volts, the economical advantages resulting from the reduction of the striking distance, particularly on the approach of the terminals, are not of very great practical consequence. By far the more important gain I have found to result from a novel effect which I have observed to follow from the action of such a medium when under pressure, upon the arc, namely, that the cross-section of the latter is reduced approximately in an inverse ratio to the pressure. As under conditions, in other respects the same, the waste of energy in an arc is proportional to the cross-section of the latter, a very important gain in economy generally results. A feature of great practical value lies also in the fact that the insulating power of the compressed medium is not materially impaired even by considerable increase in temperature, and, furthermore, that variations of pressure between wide limits, if the apparatus is properly constructed, do not interfere notably with the operation of the circuit controller. In many other respects, however, a gas under great compression, nearly fulfils the ideal requirements above mentioned, as in the sudden breaking down and quick restoration of the insulating power, and also in chemical inertness which, by proper selection of the gas, is easily secured.

In applying this feature of my invention the medium under pressure may be produced or maintained in any proper manner, the improvement not being limited in this particular to any special means for the purpose. I prefer, however, to secure the desired result by confining the circuit controller, or at least so much of the same as shall include the terminals, in a closed chamber or receptacle with rigid walls, with the interior of which communicates a small reservoir containing a liquified gas.

Referring now to the accompanying drawings for a more detailed description of the apparatus,

Fig. 1 is a diagram illustrating the general arrangement of the circuit controller and the special manner in which it is designed to be used.

Fig. 2 is a top plan view of the circuit controller.

Fig. 3 is a view partly in section and partly in elevation of the complete apparatus indicated diagrammatically in Fig. 1.

The remaining figures are central sectional views of modified forms of the apparatus, with the exception of Fig. 10, which is a sectional plan view of the upper portion of the form of apparatus shown in Fig. 9.

The general scheme of the system for use with which the improved circuit controller is more especially designed, will be understood by reference to Fig. 1. In said figure X, X represent the terminals of a source of current. A^1 is a self induction or choking coil included in one branch of the circuit and permanently connected to one side of a condenser A^{11}. The opposite terminal of this condenser is connected to the other terminal of the source through the primary A^3 of a transformer, the secondary A^4 of which supplies the working circuit containing any suitable translating devices, as A^5.

The circuit controller A which is represented conventionally, operates to make and break a bridge from one terminal of the source to a point between the choking coil A^1 and the condenser A^{11}, from which it will result that when the circuit is completed through the controller, the choking coil A^1 is short circuited and stores energy, which is discharged into the condenser when the controller circuit is broken, to be in turn discharged from the condenser through the primary A^3, when the said condenser and primary are short circuited by the subsequent completion of the controller circuit.

Figs. 2 and 3 illustrate a typical form of the circuit controller. The parts marked A, B, compose a closed receptacle of cylindrical form having a dome or extension of smaller diameter. The receptacle is secured to the end of a spindle a which is mounted vertically in bearings of any character suitable for the purpose.

Rapid rotation is imparted to the receptacle in any suitable manner, as by means of a field magnet a^1 secured to the base or frame, and an annular armature a^{11} secured to the receptacle A. The coils of the armature are connected with the plates c of a commutator secured to the receptacle A and made in cylindrical form so as to surround the socket in which the spindle a is stepped.

A body of magnetic material c^1 which serves as an armature is mounted on anti-friction bearings on an extension of the spindle a so that the receptacle and the body c^1 may have freely independent movements of rotation.

Surrounding the dome B in which the armature is contained is a core with pole pieces c^{11}, which are magnetized by coils b wound on the core. The said core is stationary, being supported by arms b^1, Fig. 2, independently of the receptacle, so that when the receptacle is rotated and the core energized, the attractive force exerted by the poles c^{11} upon the armature c^1 within the receptacle A holds the said armature against rotation. To prevent loss from currents set up in the shell of the dome B, the latter should be made of German silver or other similar precaution taken.

An arm b^{11} is secured to the armature c^1 within the receptacle A and carries at its end a short tube d bent as shown in Fig. 2, so that one end is tangential to the receptacle wall, and the other directed towards the center of the same.

Secured to the top plate of the receptacle A are a series of conducting plates d^1. The part of the top plate d^{11} from which said conducting plates depend, is insulated from the receptacle proper by insulating packing rings, but is electrically connected with the dome B, and in order to maintain electrical connection from an external circuit to the conductors d^1 a mercury cup e is set in the top of the dome, into which cup extends a stationary terminal plug e^1.

A small quantity of a conducting fluid, such as mercury, is put into the receptacle A and when the latter is rotated, the mercury, by centrifugal action, is forced out towards the periphery and rises up along the inner wall of the receptacle. When it reaches the level of the open mouthed tube d, a portion is taken up by the latter which is stationary, and forced by its momentum through the tube and discharged against the conductors d^1 as the latter pass in rapid succession by the orifice of said tube.

In this way the circuit between the receptacle and the conductors d^1 is completed during the periods in which the stream or jet of mercury impinges upon any of the said conductors and broken whenever the stream is discharged through the spaces between them.

The feature of my invention which consists in maintaining an atmosphere of inert gas under pressure in the receptacle containing the circuit controller is applicable to all of the forms of circuit controller herein described. A special arrangement for the purpose, however, is shown in Fig. 4, which exhibits also a modified arrangement of the circuit controlling mechanism designed to overcome the objection which in some cases might lie to such forms as those of Figs. 2 and 3 from the amount of work which the conducting fluid is required to perform at very high speeds.

Referring to Fig. 4, the receptacle A has a head B secured by a gas-tight insulating joint. A spindle C is screwed or otherwise secured centrally in the head B and on this is mounted on antifriction bearings a sleeve D to which rotary motion may be imparted in any suitable manner, as by securing to said sleeve D a laminated magnetic core a^1 and placing around the portion of the head B which contains it a core a^{11} provided with coils and constituting the primary element of a motor capable of producing a rotary field of force which will produce a rapid rotation of the secondary element or core a^1.

To the depending end of the sleeve D is secured a conducting disk D^1 with downwardly extending teeth or projections d^1.

To the sleeve or to the disk D^1 is also attached, but insulated therefrom, a shaft D^{11} having a spiral blade E^1 and extending down into a well or cylindrical recess in the bottom of the receptacle.

One or more ducts or passages E lead from the bottom of this well to points near the path of the conducting teeth of the disk D^1 so that by the rotation of the screw E^1 the conducting fluid will be forced up through the duct or ducts from which it issues in a jet or jets against the rotating conductor.

To facilitate this operation, the well is surrounded by a flange E^{11} containing passages e^{11} which permit the conducting fluid to flow from the receptacle into the well, and having bevelled sides which serve as a shield to deflect the fluid expelled from the ducts through the spaces in the conductor to the bottom of the receptacle.

Any suitable reservoir M is placed in communication with the interior of the main receptacle and partially filled with a liquified gas which maintains a practically inert atmosphere under pressure in the receptacle. Preferably, though mainly as a matter of convenience, the reservoir M is a metal cup with a hollow central stem F^1, the opening for the passage of gas being controlled by a screw-valve in the top of the cup. The cup is screwed onto the end of the spindle C, through which is a passage F^{11} leading into the interior of the receptacle.

To insure a good electrical connection between the sleeve D and the spindle C, I provide in the former a small chamber f which contains mercury, and into which the end of the spindle C extends.

Fig. 5 illustrates a modification of the circuit controller which involves two prominent features useful in devices of this character. One, that it provides for maintaining, in a rotating receptacle, a stationary jet or jets which, by impinging on a rigid conductor, maintain the latter in rotation, thereby securing the requisite rapidly intermittent contact between the two; the other, that it utilizes the rotation of such rigid conductor as a means for opposing or preventing the movement of its own supports in the direction of rotation of the receptacle, thereby securing, among other things, an approximately constant relative movement between the parts, a feature which, in devices of this kind, is often very desirable.

In said Fig. 5 the receptacle A is provided with trunnions which have bearings in standards f^{11}, f^{11}, and which permit the rotation of the receptacle about a horizontal axis.

In the particular form of device under consideration the receptacle is divided into two parts insulated by a washer G and held together by insulated bolts G^1 with nuts G^{11}.

A body I is supported by trunnions g having bearings in the ends of the receptacle and concentric with the axis of rotation of the same. The weight of the body I, being eccentric to this axis, tends to oppose its turning about the axis when the receptacle is rotated.

Upon the body or support I, but insulated therefrom, is secured a vertical standard g^1 in which there is a freely rotatable spindle f^1 carrying a disk g^{11} with radial arms inclined to the plane of the disk so as to form vanes d^1.

Arms i, i^1 are also secured to the body I and are formed with, or carry at their ends, ducts or tubes d with one end directed towards and opening upon the vanes d^1, and the other end close to the inner wall of the receptacle and opening in the direction opposite to that of its rotation.

A suitable quantity of mercury is placed in the receptacle before the latter is sealed or closed.

The operation of the device is as follows : The receptacle is started in rotation, and, as it acquires a high velocity, the mercury or other conducting fluid is caused, by centrifugal action, to distribute itself in a layer over the inner peripheral surface.

As the tubes or ducts d do not take part in the rotation of the fluid, being held at the start by the weighted body I, they take up the mercury as soon as it is carried to the points where the ducts open, and discharge it upon the vanes of the disk g^{11}.

By this means the disk is set in rapid rotation, establishing the contact between the two sides of the receptacle which constitute the two terminals of the circuit controller whenever the two streams or jets of fluid are simultaneously in contact with the vanes, but breaking the contact whenever the jets discharge through the spaces between the vanes.

The chief object of employing two insulated jets rather than one is to secure a higher velocity of approach and separation, and in this respect the device may be still further improved by providing any number of such insulated compartments and jets and a corresponding number of rotating rigid conductors.

The disk g^{11}, having acquired a very rapid rotation, operates by gyrostatic action to prevent any tendency of the body I to rotate or oscillate, as such movement would change the plane of rotation of the disk. The movement of the parts, therefore, and the operation of the device as a whole is very steady and uniform and a material practical advantage is thereby secured. The speed of the disk will be chiefly dependent on the velocity of the streams and pitch of the blades, and it is, of course, necessary, in order to produce a constant speed of rotation of the disk, that the velocity of the streams be constant. This is accomplished by rotating the receptacle with a constant speed, but when this is impracticable and the uniformity of motion of the disk very desirable, I resort to special means to secure this result, as by providing overflowing reservoirs i^{11}, i^{11}, as indicated by dotted lines, from which the fluid issues upon the vanes with constant velocity, though the speed of the receptacle may vary between wide limits.

It will be understood that the jets which effect the electrical contact, need not necessarily be utilized to drive the disk, but that for this latter purpose additional jets may be provided and applied to an insulated portion of the disk or to a body connected therewith, in which case such jets may be made to impinge instead of upon the peripheral portions, on parts situated nearer to the axis of rotation, thus causing a more rapid movement of the disk. The jets may also be produced in many other ways.

To still further increase the rate of relative movement of the terminals, each may be rotated with respect to the other. This may be effected in various ways, of which the device shown in Fig. 6 is an example. In said figure H designates a casting of cylindrical form within which is a standard or socket in which is mounted a vertical spindle a carrying the circuit controlling mechanism.

The said mechanism is contained in a receptacle A, the top or cover of which is composed of an annular plate and a cap or dome B, the latter being of insulating material or of a metal of comparatively high specific resistance, such as German silver. Any suitable means may be employed to effect the rotation of the receptacle, the particular device shown for this purpose being an electro-magnetic motor, one element a^1 of which is secured to the spindle a or receptacle A, and the other a^{11} to the box or case H. Within the receptacle A, and secured to the top of the same, but insulated therefrom, is a circular conductor with downwardly extending projections or teeth d^1. This conductor is maintained in electrical connection with a plate H^1 outside of the receptacle by means of screws or bolts H^{11} passing through insulated gaskets in the top of the receptacle A.

Within the latter is a standard or socket h, in which is mounted a spindle h^1 concentric with the axis of the receptacle.

Any suitable means may be provided for rotating the spindle independently of the receptacle A, but for this purpose I again employ an electro-magnetic motor, one element h^{11} of which is secured to the spindle h^1 within the receptacle A, and the other j is secured to the box H and surrounds the cap or dome B, within which is mounted the armature h^{11}.

Depending from the spindle h^1 or the armature h^{11} is a cylinder, to which are secured arms b^{11}, b^{11} extending radially therefrom and supporting short tubes or ducts d between the peripheral walls of the receptacle A and the series of teeth or projections d^1.

The tubes d have openings at one end in close proximity to the inner wall of the receptacle A and turned in a direction opposite to that in which the latter is designed to rotate, and at the other end orifices which are adapted to direct a stream or jet of fluid against the projections d^1.

To operate the apparatus the receptacle A, into which a suitable quantity of mercury is first poured, and the spindle h^1 are both set in rotation by their respective motors and in opposite directions. By the rotation of receptacle A the conducting fluid is carried by centrifugal force up the sides or walls of the same and is taken up by the tubes or ducts d and discharged against the rotating conductors d^1. If, therefore, one terminal of the circuit be connected with any part of the receptacle A, or the metal portions of the instrument in electrical connection therewith, and the other terminal be connected to the plate H^1, the circuit between these terminals will be completed whenever a jet from one of the ducts d is discharged against one of the projections d^1, and interrupted when the jets are discharged through the spaces between such projections.

Instead of using a solid or rigid conductor for one of the terminals or contacts and a conducting fluid for the other, I may use a conducting fluid for both, under conditions which permit of a rapidly intermittent contact between them, as will be seen by reference to Fig. 7.

The receptacle, as shown in this figure, is composed of two parts insulated from each other and supported by trunnions so as to rotate about a horizontal axis. The abutting ends of the two parts are formed with inwardly extending flanges J^1 which divide the peripheral portion of its interior into two compartments J^{11} and K^{11}.

Into one of these compartments, as J^{11}, extends a spindle K, having its bearing in one end of the receptacle A, and the trunnion secured to or extending therefrom. Into the other compartment K^{11} extends a spindle K^1 similarly journalled in the opposite end of the receptacle A and its trunnion.

Each spindle carries or is formed with a weighted arm I, which remaining in a vertical position holds its spindle stationary when the receptacle is revolved.

To the weighted arm or spindle K is secured a standard L carrying a tube d with one open end in close proximity to the inner peripheral wall of the compartment J^{11} and the other directed towards the axis, but inclined towards the opposite compartment.

To the weighted arm or spindle K^1 is similarly secured to standard L^1 which is hollow and constitutes a portion of a duct or passage which extends through a part of the spindle and opens through a nozzle l^{11} into a circular chamber l in the wall of the receptacle. From this chamber run passages l^1 to nozzles m in position to discharge jets or streams of liquid in such directions as to intersect, when the nozzles are rotated, a stream issuing from the end of tube d.

In each portion or compartment of the receptacle is placed a quantity of mercury, and the ends of the tubes are provided with openings which take up the mercury when, on the rotation of the receptacle, it is carried by centrifugal force against the peripheral wall. The mercury when taken up by the tube d issues in a stream or jet from the inner end of said tube and is projected into the compartment K^{11}. The mercury taken up by the tube L^1 runs into the circular chamber l from which it is forced through the passages l^1 to the nozzles m from which it issues in jets or streams directed into the compartment J^{11}. As the nozzles m revolve the streams which issue from them will therefore be carried across the path of the stream which issues from the tube d and which is stationary, and the circuit between the two compartments will be completed by the streams whenever they intersect, and interrupted at all other times.

The continuity of the jets or streams is not preserved, ordinarily, to any great distance beyond the orifices from which they issue, and hence they do not serve as conductors to electrically connect the two sides of the receptacle beyond their point of intersection with each other.

It will be understood that so far as the broad feature of maintaining the terminal jets is concerned, widely different means may be employed for the purpose and that the spindles mounted in free bearings concentrically with the axis of rotation of the receptacle and held against rotation by the weighted arms constitute but one specific way of accomplishing this result. This particular plan, however, has certain advantages and may be applied to circuit controllers of this class generally whenever it is necessary to maintain a stationary or nearly stationary body within a rotating receptacle.

It is further evident, from the nature of the case that it is not essential that the jet or jets in one compartment or portion of the instrument should be stationary and the others rotating, but only that there should be such relative movement between them as to cause the two sets to come into rapidly intermittent contact in the operation of the device.

The number of jets, whether stationary or rotating, is purely arbitrary, but since the conducting fluid is directed from one compartment into the other, the aggregate amount normally discharged from the compartments should be approximately equal. However, since there always exists a tendency to project a greater quantity of the fluid from that compartment which contains the greater into that which contains the lesser amount no difficulty will be found in this respect in maintaining the proper conditions for the satisfactory operation of the instrument.

A practical advantage, especially important when a great number of breaks per unit of time is desired, is secured by making the number of jets in one compartment even and in the other odd, and placing each jet symmetrically with respect to the center of rotation. Preferably the difference between the number of jets should be one. By such means, the distances between the jets of each set are made as great as possible and hurtful short-circuits are avoided.

For the sake of illustration, let the number of jets or nozzles *d* in one compartment be nine, and the number of those marked *m* in the other compartment ten, then by one revolution of the receptacle there will be ninety makes and breaks.

To attain the same result with only one jet as *d* it would be necessary to employ ninety jets *m* in the other compartment, and this would be objectionable, not only because of the close proximity of the jets, but also of the great quantity of fluid required to maintain them.

In the use of the instrument as a circuit controller it is merely necessary to connect the two insulated parts of the receptacle to the two parts of the circuit respectively.

In instruments of this character in which both terminals are formed by a liquid element, there is no wear or deterioration of the terminals and the contact between them is more perfect. The durability and efficiency of the devices are thus very greatly increased.

I may also secure the same result by a modified form of circuit controller, in which the closure of the circuit is effected through two parts of conducting fluid, but in this case instead of breaking the circuit by the movement of these two parts or terminals, as in the device of Fig. 7, I separate them periodically by the interposition of an insulator which is preferably solid and refractory.

For example, I provide a plate or disk with teeth or projections of glass, lava or the like, which are caused by the rotation of the disk to pass through the jet or fluid conductor and thus effect a make and break of the circuit.

By means of such a device the breaks always occur between fluid terminals, and hence deterioration and consequent impairment of the qualities of the apparatus is avoided.

In Fig. 8, which shows this form of controller, the receptacle which contains the terminals is mounted on a spindle *a* in a suitable socket or support so as to rotate freely.

The means shown for rotating the receptacle are the same as in Fig. 3, although any other might be employed.

In the spindle *a*, and concentric with its axis, is a spindle M supported on ball-bearings or otherwise arranged to have a free movement of rotation relatively to the spindle *a* so as to be as little as possible influenced by the rotation of the latter.

Any convenient means is provided to oppose or prevent the rotation of the spindle M during the rotation of the receptacle. In the particular arrangement here shown for this purpose a weight or weighted arm I is secured to the spindle M, and eccentrically to the axis of the latter, and, as the bearing for the spindle *a* holds the same at an angle to the vertical, this weight acts by gravity to hold the spindle M stationary.

Secured to the top or cover of the receptacle A, by a stud m^1 which passes through an insulating bushing in said cover and is held by a nut m^{11}, is a circular disk M^1 of conducting material, preferably iron or steel, having its edge turned downwardly and then inwardly to provide a peripheral through on the underside of the disk.

To the under side of the disk M^1 is secured a second disk M^{11} having downwardly inclined peripheral projections *n*, *n*, of insulating and preferably refractory material in a circle concentric with the disk M^1.

A tube or duct *d* is mounted on the spindle M or the weight I, and is so arranged that the orifice at one end is directed outwardly towards the trough of the disk M^1 while the other lies close to the inner peripheral wall of the receptacle so that if a quantity of mercury or other conducting fluid be placed in the receptacle and the latter rotated, the tube or duct *d*, being held stationary, will take up the fluid which is carried by centrifugal action up the side of the receptacle and deliver it in a stream or jet against the trough or flange of the disk M^1 or against the inner surfaces of the projections *n* of disk M^{11}, as the case may be.

Obviously, since the two disks M^1 and M^{11} rotate with respect to the jet or stream of fluid issuing from the duct *d*, the electrical connection between the receptacle and the disk M^1 through the fluid will be completed by the jet when the latter passes to the disk M^1 between the projections *n*, and will be interrupted whenever the jet is interrupted by the said projections.

The rapidity and the relative duration of the makes and breaks is determined by the speed of rotation of the receptacle and the number and width of the intercepting projections *n*.

By forming that portion of the disk M^1 with which the jet makes contact, as a trough, which will retain, when in rotation, a portion of the fluid directed against it, a very useful feature is secured. The fluid, under the action of centrifugal force accumulates in and is distributed along the trough and forms a layer over the surface upon which the jet impinges. By this means a very perfect contact is always secured, and all deterioration of the terminal surfaces avoided.

It is not necessary that the conducting fluid which forms one of the terminals, should be in the form of a jet issuing from the orifice of a tube or duct. The same results may be secured by the use of a body or stream of the fluid maintained in rapid movement in other ways, and in Figs. 9 and 10 I have illustrated a means for accomplishing this.

The receptacle A is mounted and rotated in the case in the same manner as in Fig. 8, and a spindle M carrying an eccentric weight I is also employed.

Attached to the spindle M or weight I is an insulated bracket O carrying a standard or socket O^1 in which is mounted, on antifriction bearings, a spindle O^{11}. Secured to this latter is a plate with radial arms *o* from which depend vanes or blades o^1, with projections o^{11} extending radially therefrom. A shield or screen P encloses the vanes except on the side adjacent to the inner periphery of the receptacle A.

A small quantity of a conducting fluid is placed in the receptacle, and in order to secure a good electrical connection between the vanes o^1 and a terminal on the outside of the receptacle, a small mercury cup p in metallic contact with the vanes through the bracket O and socket O^1 is secured to the weight I. A metal stud set in an insulated bolt m^1 projects into the cup p through a packed opening in its cover. One terminal of the circuit controlling mechanism will thus be any part of the metal receptacle, and the other the insulated bolt m^1.

To operate the apparatus, the receptacle is set in rotation, and as its speed increases the mercury or other conducting fluid which it contains is carried, by centrifugal force, up the sides of the inner wall over which it spreads in a layer. When this layer rises sufficiently to encounter the projections o^{11} on the blades or vanes o^1, the latter are set in rapid rotation, and the electrical connection between the terminals of the apparatus is thereby made and broken, it may be, with very great rapidity.

The projections o^{11} are preferably placed at different heights on the vanes o^1 so as to secure greater certainty of good contact with the mercury film when in rapid rotation.

In all of the several modified forms of my improved apparatus above described, the receptacle which contains or encloses the parts or elements of the circuit controller proper, is rotated; but this is not essential, since, by proper modification of the apparatus the necessary relative movement may be secured between the terminals when contained in a stationary receptacle.

This is illustrated in Fig. 11, in which a stationary receptacle A is shown as composed of top and bottom plates of metal and a cylindrical portion of insulating material, such as porcelain. Within the receptacle, and preferably integral with the side walls, are two annular troughs W, W^1, which contain a conducting fluid, such as mercury. Terminals R, R^1, passing through the bottom of the receptacle through insulating and packed sleeves, afford a means of connecting the mercury in the two troughs with the conductors of the circuit.

Surrounding that portion of the device in which the troughs W, W^1, lie is a core A^{11} wound with coils arranged in any suitable and well-known manner to produce, when energized by currents of different phase, a rotating magnetic field in the space occupied by the two bodies of mercury. To intensify the action, a circular laminated core r is placed within the receptacle.

If by this or any other means, the mercury is set in motion and caused to flow around in the troughs, and if a conductor be mounted in position to be rotated by the mercury, and when so rotated to make intermittent contact therewith, a circuit controller may be obtained of novel and distinctive character, and capable of many useful applications independently of the other features which are embodied in the complete device which is illustrated.

For the present purpose I provide in the center of the receptacle a socket in which is mounted a spindle R^{11} carrying a disk r^1. Depending from said disk are arms r^{11} which afford bearings, for a shaft S supporting two star-shaped wheels S^1, S^{11}, arranged to make contact with the mercury in the two troughs respectively. The shaft S is mounted in insulated bearings, so that when both wheels are in contact with mercury the circuit connecting the terminals R, R^1 will be closed. The disk r^1 carries an annular core T, and coils T^1 are supported outside of the receptacle and are preferably of the same character as those used for imparting rotation to the mercury, but the direction of rotation should be opposite to that of the mercury.

The rate of rotation of the wheel S^1, S^{11} depends upon the rate of relative movement of the mercury, and hence if the mercury be caused to flow in one direction and the wheels be carried bodily in the opposite direction, the rate of rotation and consequently the frequency of the makes and breaks will be very greatly increased over that which would be obtained if the wheels S^1, S^{11} were supported in a stationary bearing.

In all the forms of circuit controller above described in which the circulation of the conducting fluid through tubes or ducts is maintained, the force which impels the fluid is derived from the same source as that which rotates the receptacle or maintains the relative movement of the terminals. In other words, instead of employing an independent pump or like device for forcing the fluid trough the ducts, I combine in one, the two mechanisms—the controller and the means for maintaining a circulation of the conducting fluid.

It will be observed that the invention involves many features which are broadly new in instruments of this character, and is not limited to the specific forms of apparatus shown and described, but may be carried out by other and widely differing forms.

Having now particularly described and ascertained the nature of this invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. A circuit controller comprising in combination, a receptacle containing a conducting fluid, means for rapidly rotating the receptacle or the fluid therein, and a terminal or terminals supported within the receptacle and adapted to make and break electrical connection with the fluid.

2. The combination with a receptacle of a conductor or series of spaced conductors, a nozzle or tube for directing a jet or stream of fluid against the same, the nozzle and conductor being capable of movement relatively to each other, and means for maintaining a circulation of conducting fluid, contained in the receptacle, through said nozzle, and dependent for operation upon such relative movement.

3. The combination with a closed receptacle of a conductor or series of spaced conductors, a nozzle or tube for directing a jet or stream of fluid against the same, and means for forcing a conducting fluid contained in the receptacle through the said nozzle, these parts being associated within the receptacle and adapted to be operated by the application of a single actuating power.

4. The combination with a receptacle containing a series of spaced conductors, a duct within the receptacle having one of its ends directed towards the said conductors, means for maintaining a rapid movement of relative rotation between the said end and the conductors and means for maintaining a circulation of a conducting fluid contained in the receptable through the duct against the conductors, the said conductors and jet constituting respectively the terminals or elements of an electric circuit controller.

5. The combination with a receptacle capable of rotation and containing a series of spaced conductors, a duct within the receptacle having an orifice directed towards the said conductors, and an open end in position to take up a conducting fluid from a body of the same contained in the receptacle, when the latter is rotated, and direct it against the conductors, the said conductors and the fluid constituting the terminals or elements of an electric circuit controller.

6. The combination with a receptacle for containing a conducting fluid and a series of spaced conductors therein, of a duct having an orifice directed towards the said conductors and forming a conduit through which the fluid when the receptacle is rotated is forced and thrown upon the conductors.

7. The combination with a receptacle capable of rotation, and a series of conductors mounted therein, of a duct having an orifice directed towards the conductors, a holder for said duct mounted on bearings within the receptacle which permit of a free relative rotation of said receptacle and holder, and means for opposing the rotation of the said holder in the direction of the movement of the fluid while the receptacle is rotated, whereby the conducting fluid within the receptacle will be caused to flow through the duct against the conductors.

8. The combination with a receptacle and a motor for rotating the same, of a magnetic body mounted in the receptacle, a magnet exterior to the receptacle for maintaining the body stationary while the receptacle rotates, a series of conductors

in the receptacle and a duct carried by the said magnetic body and adapted to take up at one end a conducting fluid in the receptacle when the latter rotates and to direct such fluid from its opposite end against the series of conductors.

9. The combination with a receptacle for containing a conducting fluid, a series of spaced conductors within the same, and a motor, the armature of which is connected with the receptacle so as to impart rotation thereto, a magnetic body capable of turning freely within the receptacle about an axis concentric with that of the latter, a duct carried by the said body having one end in position to take up the conducting fluid and the other in position to discharge it against the spaced conductors, and a magnet exterior to the receptacle for holding the magnetic body stationary when the receptacle is rotated.

10. The combination with a closed receptacle in which is maintained an inert insulating gaseous medium under great pressure, of a circuit controller contained within the receptacle, as set forth.

11. The combination with a closed gas tight receptacle of a circuit controller contained within the same, and a vessel containing a liquefied gas, and communicating with the interior of the receptacle, as set forth.

12. The combination with a circuit controlling mechanism, one part or terminal of which is a conducting fluid, such as mercury, of a receptacle enclosing the same and means for maintaining an inert gas under pressure in the receptacle.

13. The combination with a conductor or series of conductors constituting one terminal of a circuit controller, means for maintaining a stream or jet of conducting fluid as the other terminal with which the conductor makes intermittent contact, a closed receptacle containing the terminals, and means for maintaining an inert atmosphere under pressure in the receptacle.

14. A device for making and breaking an electric circuit comprising, in combination, means for maintaining a jet or stream of conducting fluid which constitutes one terminal, a conductor or conductors making intermittent contact with the jet and constituting the other terminal and a receptacle enclosing and excluding oxygen from the said terminals.

15. The combination of a casing, a conductor or series of spaced conductors mounted therein, a motive device for rotating the said conductors, and a pumping device rigidly connected with the conductors for maintaining a stream or streams of conducting fluid directed against the rotating conductors, the said conductors and the fluid constituting respectively the terminals of a circuit controller.

16. The combination of a casing, a conductor or series of spaced conductors mounted therein, a motor for rotating the same, one or more ducts or channels from a receptacle containing a conducting fluid and directed towards the conductors, and a pump operated by the motor for forcing the conducting fluid through the duct or ducts against the conductors, the conductors and the fluid constituting the terminals of an electric circuit controller.

17. The combination with a receptacle containing a conducting fluid, of a conductor mounted within the receptacle, means for rotating the same, a screw rotating with the conductor and extending into a well in which the fluid collects, and a duct or ducts leading from the well to points from which the fluid will be directed against the rotating conductor.

18. The combination with the receptacle, of a spindle secured to its head or cover, a magnetic core mounted on the spindle within the receptacle, means for rotating said core, a conductor rotated by the core, and a pumping device, such as a screw rotated by the core and operating to maintain a jet or jets of conducting fluid, against the conductor, when in rotation.

19. The combination in a circuit controller with a closed receptacle, of a rigid body mounted within the receptacle and through which the circuit is intermittently established, and means for directing a jet or stream of a fluid contained in the receptacle against the said body so as to effect its rotation, as set forth.

20. The combination in a circuit controller of a jet of conducting fluid con-

stituting one terminal, a conductor adapted to be rotated by the force of the jet, and in its rotation to make intermittent contact therewith, and an enclosing receptacle, as set forth.

21. In an electric circuit controller, the combination of a closed receptacle, a conducting body therein adapted to be rotated by the impingement thereon of a jet or stream of conducting fluid, and means for maintaining such a jet and directing it upon the said conductor, as set forth.

22. In a circuit controller, the combination with a rotary receptacle of a body or part mounted within the receptacle and concentrically therewith, a conducting terminal supported by said body and capable of rotation in a plane at an angle to the plane of rotation of the receptacle so as to oppose, by gyrostatic action, the rotation of the support, and means for directing a jet of conducting fluid against the said terminal, as set forth.

23. In a circuit controller, the combination with a rotary receptacle of a support for a conductor mounted thereon concentrically with the receptacle and a gyrostatic disk carried by the support and adapted, when rotating, to oppose its movement in the direction of rotation of the receptacle, as set forth.

24. In a circuit controller, the combination with a rotary receptacle containing a conducting fluid, a support mounted within the receptacle, means for opposing or preventing its movement in the direction of rotation of the receptacle, one or more tubes or ducts carried thereby and adapted to take up the fluid from the rotating receptacle and discharge the same in jets or streams, and a conductor mounted on the support and adapted to be rotated by the impingement thereon of said jet or jets, as set forth.

25. The combination in a circuit controller of a rotary receptacle, one or more tubes or ducts and a support therefor capable of rotation independently of the receptacle, a conductor mounted on said support in a plane at an angle to that of rotation of the receptacle, and adapted to be maintained in rotation by a jet of fluid taken up from the receptacle by and discharged upon it from the said tube or duct, when the receptacle is rotated.

26. The combination with a rotary receptacle of one or more tubes or ducts, a holder or support therefor mounted on bearings within the receptacle, which permit of a free relative rotation of said receptacle and holder, a disk with a bearing on the said holder and having its plane of rotation at an angle to that of the receptacle, the disk being formed or provided with conducting vanes, upon which a jet of conducting fluid, taken up by the tube or duct from the receptacle when in rotation, is directed.

27. A circuit controller comprising in combination means for producing streams or jets of conducting liquid forming the terminals, and means for bringing the jets or streams of the respective terminals into intermittent contact with each other, as set forth.

28. In a circuit controller, the combination with two sets of orifices adapted to discharge jets in different directions, means for maintaining jets of conducting liquid through said orifices, and means for moving said orifices relatively to each other so that the jets from those of one set will intermittently intersect those from the other, as set forth.

29. The combination in a circuit controller of ducts and means for discharging therefrom streams or jets of conducting fluid in electrical contact with the two parts of the circuit respectively, the orifices of said ducts being capable of movement relatively to each other, whereby the streams discharged therefrom will intersect at intervals during their relative movement, and make and break the electric circuit, as set forth.

30. In a circuit controller the combination with one or more stationary nozzles and means for causing a conducting fluid forming one terminal to issue therefrom, of one or more rotating tubes or nozzles, means for causing a conducting liquid forming the other terminal to issue therefrom, the said rotating nozzles being

movable through such a path as to cause the liquid issuing therefrom to intersect that from the stationary nozzles as set forth.

31. The combination with a rotating receptacle divided into two insulated compartments, a spindle in one compartment with its axis concentric with that of the receptacle, means for opposing the rotation of said spindle, and a tube or duct carried by the spindle and adapted to take up a conducting fluid at one end from the inner periphery of the compartment when the receptacle is rotated and direct it from the other end into the other compartment, of a similar spindle in the other compartment and means for opposing its rotation, a tube carried by the spindle and having an opening at one end near the inner periphery of the compartment and discharging into a chamber from which lead one or more passages to nozzles fixed to the rotating receptacle and adapted to discharge across the path of the jet from the stationary nozzle, as set forth.

32. In a circuit controller the combination with a rotating receptacle of a body mounted thereon and formed or provided with a weighted portion eccentric to its axis which opposes its rotation and a tube or duct carried by said body and adapted to take up a conducting fluid from the rotating receptacle, as set forth.

33. In a circuit controller the combination of two sets of terminals symmetrically arranged about an axis of rotation and adapted to be brought successively into contact with each other, the number of terminals in one set being even and in the other odd, as set forth.

34. In a circuit controller the combination of two sets of terminals symmetrically arranged about an axis of rotation and adapted to be brought successively into contact with each other, there being one more terminal in one set than in the other, as set forth.

35. In a circuit controller the combination of two sets of nozzles and means for projecting from the same, jets of conducting fluid which constitute respectively the terminals of the controller, means for moving the nozzles relatively to each other so that the jets of the two sets are brought successively into contact, the nozzles of each set being arranged symmetrically about an axis of rotation, there being one more nozzle in one set than in the other.

36. In an electrical circuit controller, the combination with means for producing a stream or jet of conducting fluid which forms a path for the electric current of a body adapted to be intermittently moved through and to intercept the stream or jet, as set forth.

37. In an electrical circuit controller, the combination with a rigid terminal, of means for directing against such terminal a jet or stream of conducting fluid in electrical connection with the other terminal, and a body adapted to be intermittently moved through and to intercept the jet or stream, as set forth.

38. In an electrical circuit controller, the combination with a rigid terminal, of means for directing against such terminal a jet or stream of conducting fluid in electrical connection with the other terminal, a body having a series of radial projections and means for rotating the same so that the said projections will intermittently intercept the stream or jet, as set forth.

39. In a circuit controller, the combination with a rotary conductor forming one terminal, means for directing against such terminal a jet or stream of conducting fluid in electrical connection with the other terminal, and a body with spaced projections mounted to rotate in a path that intercepts the jet or stream of fluid, as set forth.

40. In a circuit controller, the combination with a conductor forming one terminal, and means for directing intermittently against such terminal a jet or stream of fluid in electrical connection with the other terminal, the part of said conductor upon which the jet or stream impinges being formed or arranged so as to retain, on its surface, a portion of the conducting fluid, as set forth.

41. The combination of the receptacle, a conducting disk secured within it, the insulated disk with peripheral projections and the stationary tube or duct for

directing a stream or jet of conducting fluid towards the conducting disk and across the path of the projections O, as set forth.

42. The combination of the receptacle, the conducting disk with a peripheral trough shaped flange, the insulated disk with peripheral projections O, and the stationary tube or duct for directing a stream or jet of conducting fluid into the trough shaped flange of the conducting disk and across the path of the projections O, as set forth.

43. A circuit controller comprising, in combination, a closed receptacle containing a fluid, means for rotating the receptacle, a support mounted within the receptacle, means for opposing or preventing its movement in the direction of rotation of the receptacle, and a conductor carried by said support and adapted to make and break electric connection with the receptacle through the fluid, as set forth.

44. A circuit controller comprising, in combination, a terminal capable of rotation and formed or provided with radiating contacts, a closed receptacle containing a fluid which constitutes the opposite terminal, means for rotating the receptacle, a support therein for the rotating terminal, and means for opposing or preventing the rotation of the support in the direction of the rotation of the receptacle, as set forth.

45. In a circuit controller, the combination with a receptacle capable of rotation about an axis inclined to the vertical and containing a fluid which constitutes one terminal, a second terminal mounted within the receptacle, on a support capable of free rotation relatively to the receptacle, and a weight eccentric to the axis of rotation of the support for said terminal for opposing or preventing its movement in the direction of the rotation of the said receptacle, as set forth.

46. The combination with a receptacle mounted to revolve about an axis inclined to the vertical, of a spindle within the receptacle and concentric with its axis, a weight eccentric to the spindle, and a terminal carried by the said spindle, and adapted to be rotated by a body of conducting fluid contained in the receptacle when the latter is rotated, as set forth.

47. The combination with a receptacle mounted to rotate about an axis inclined to the vertical, a spindle within the receptacle and concentric with its axis, a weighted arm attached to said spindle, a bracket or arm also secured to said spindle, a rotary terminal with radiating contact arms or vanes mounted on said bracket in position to be rotated by a body of conducting fluid contained in said receptacle when said fluid is displaced by centrifugal action, as set forth.

48. In a circuit controller, the combination with two terminals or sets of terminals, one of which is composed of a conducting fluid, of means for imparting to said terminals movements of rotation in opposite directions, as set forth.

49. The combination in a circuit controller of one or more bodies of conducting fluid and a conductor or conductors constituting, respectively, the terminals of said controller, and means for rotating said terminals in opposite directions, as set forth.

50. The combination in a circuit controller of a receptacle and means for rotating the same, one or more tubes or ducts mounted within the same and capable of rotation independently of the receptacle, means for imparting rotation to said ducts, and a conductor or series of conductors moving with the receptacle, in position to intermittently intercept jets of conducting fluid taken up by the ducts, as set forth.

51. In a circuit controller, the combination with a receptacle containing a conducting fluid, means for imparting a movement of rotation to the fluid, and a conductor adapted to be rotated by the movement of said fluid and to thereby make and break electric connection with the fluid, as set forth.

52. In a circuit controller, the combination with a terminal or series of terminals, contained in a receptacle, and a device operating by centrifugal action for taking

up a conducting fluid in said receptacle and delivering it directly or indirectly in a jet or stream upon said terminal or terminals intermittently, as set forth.

Dated this 8th day of June 1898.

HASELTINE, LAKE & Co.,
45, Southampton Buildings, London, W.C.,
Agents for the Applicant.

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A.D. 1898. June 8. No. 12,866.
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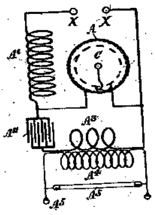

Fig. 1

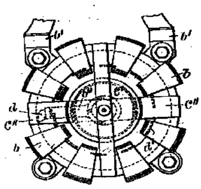

Fig. 2

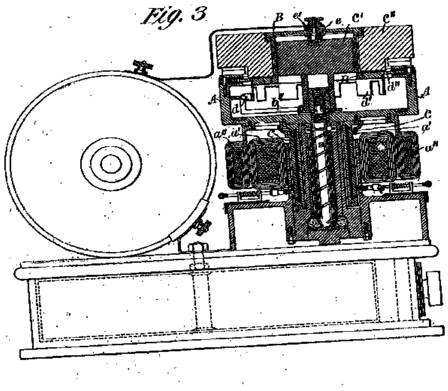

Fig. 3

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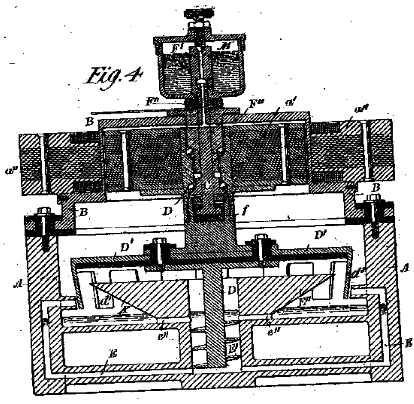

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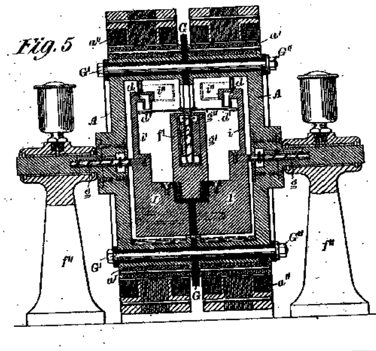

Fig. 5

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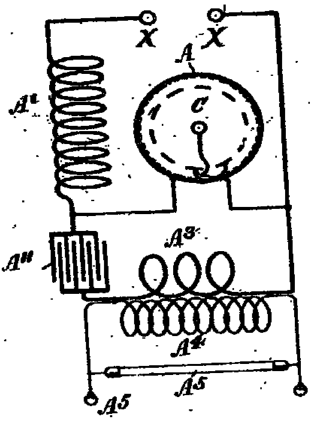

Fig. 1

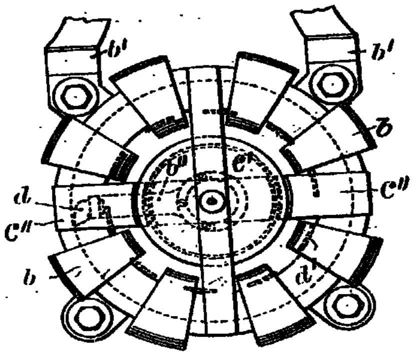

Fig. 2

Fig. 3

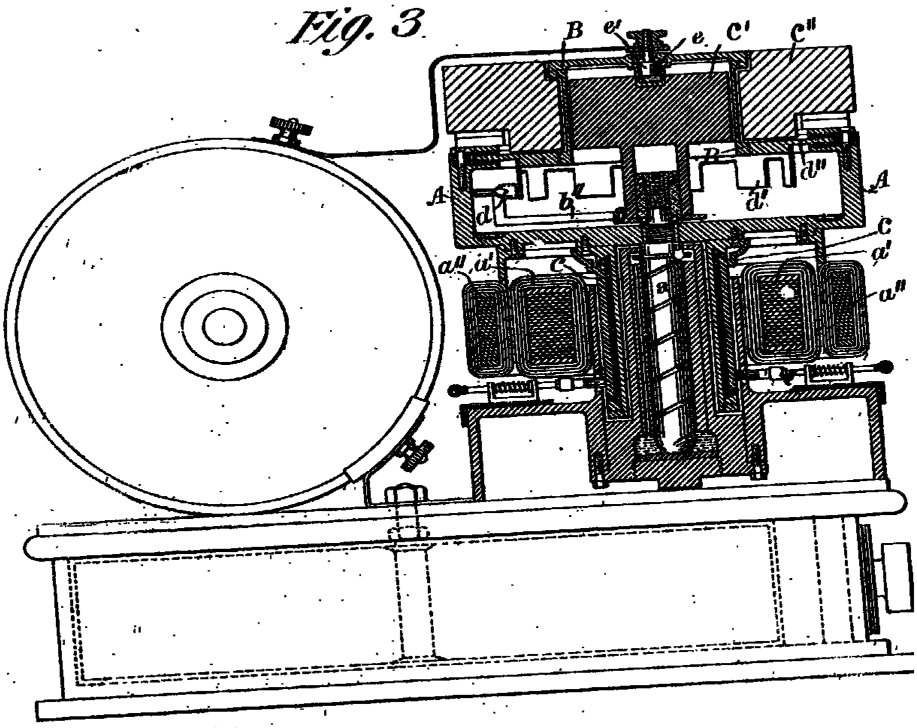

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Fig. 4

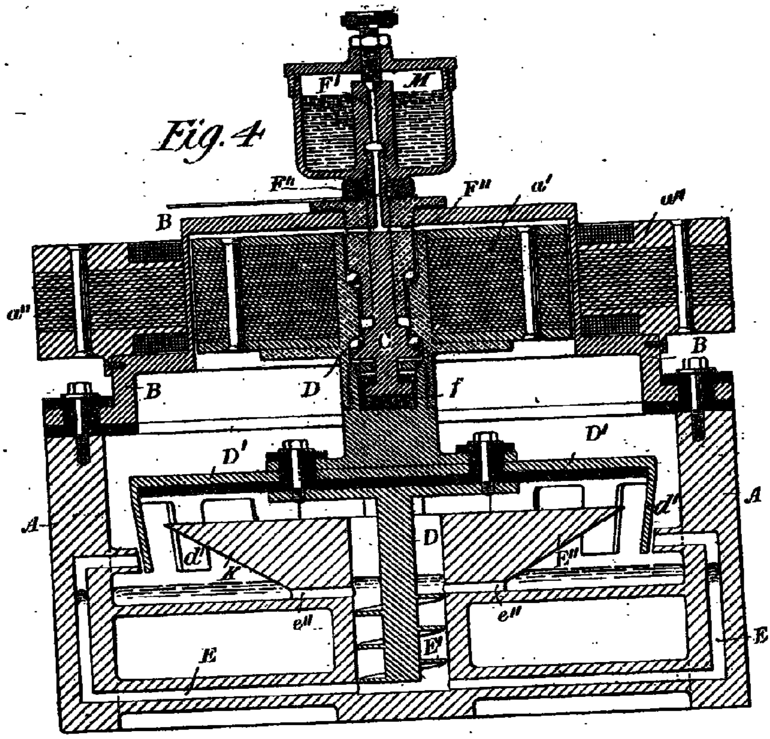

Fig. 5

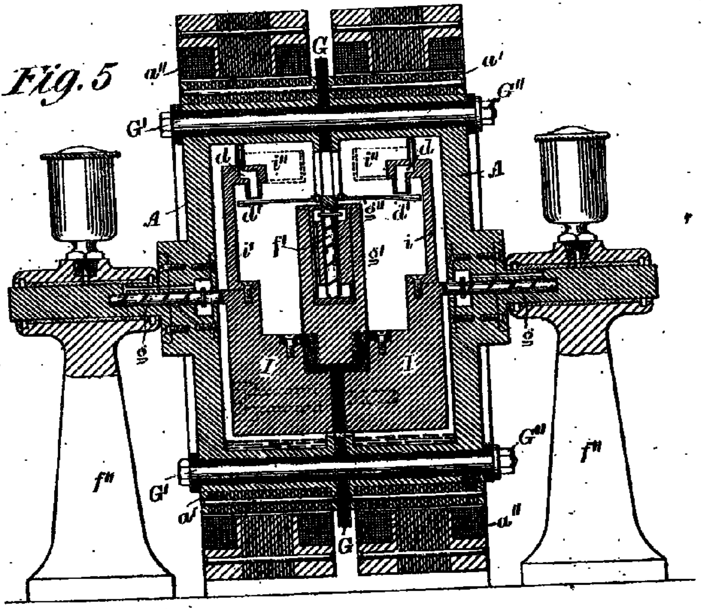

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Fig. 6

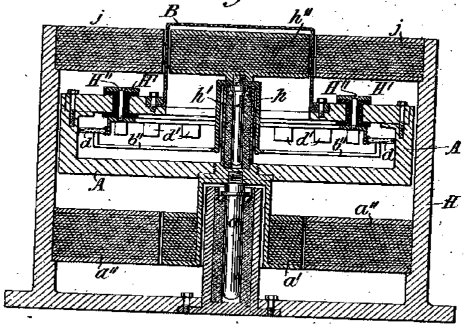

Fig. 7

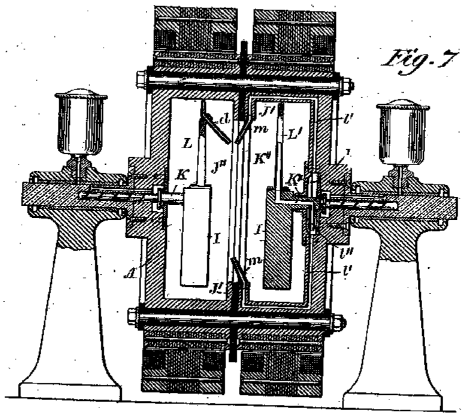

Fig. 8

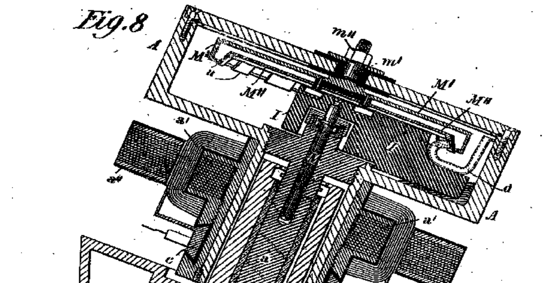

Fig. 11

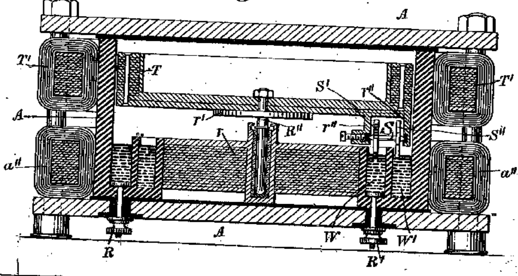

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Fig. 6

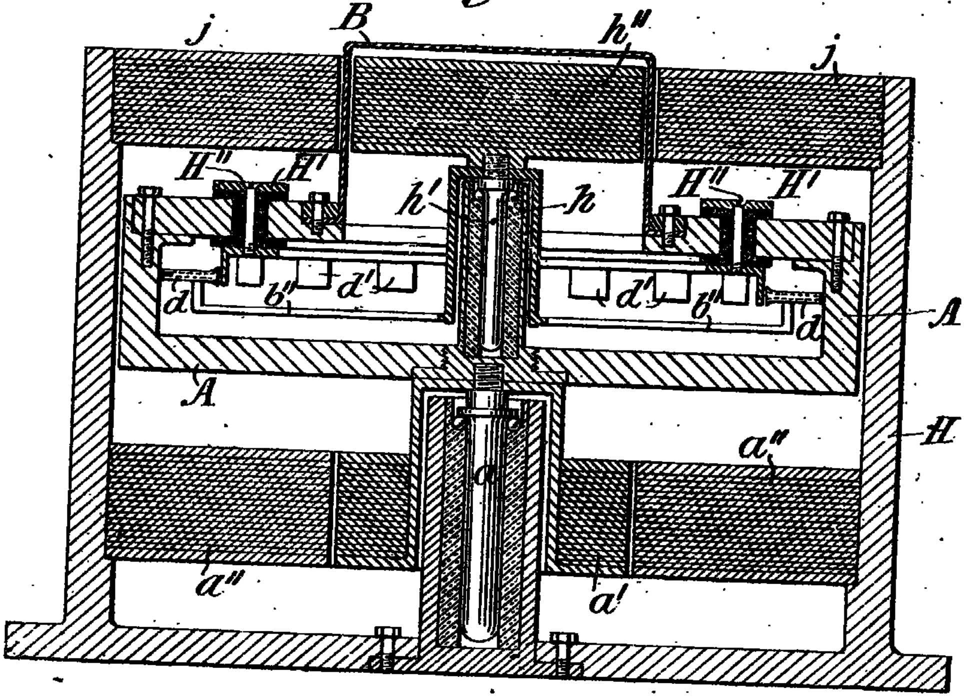

Fig. 7

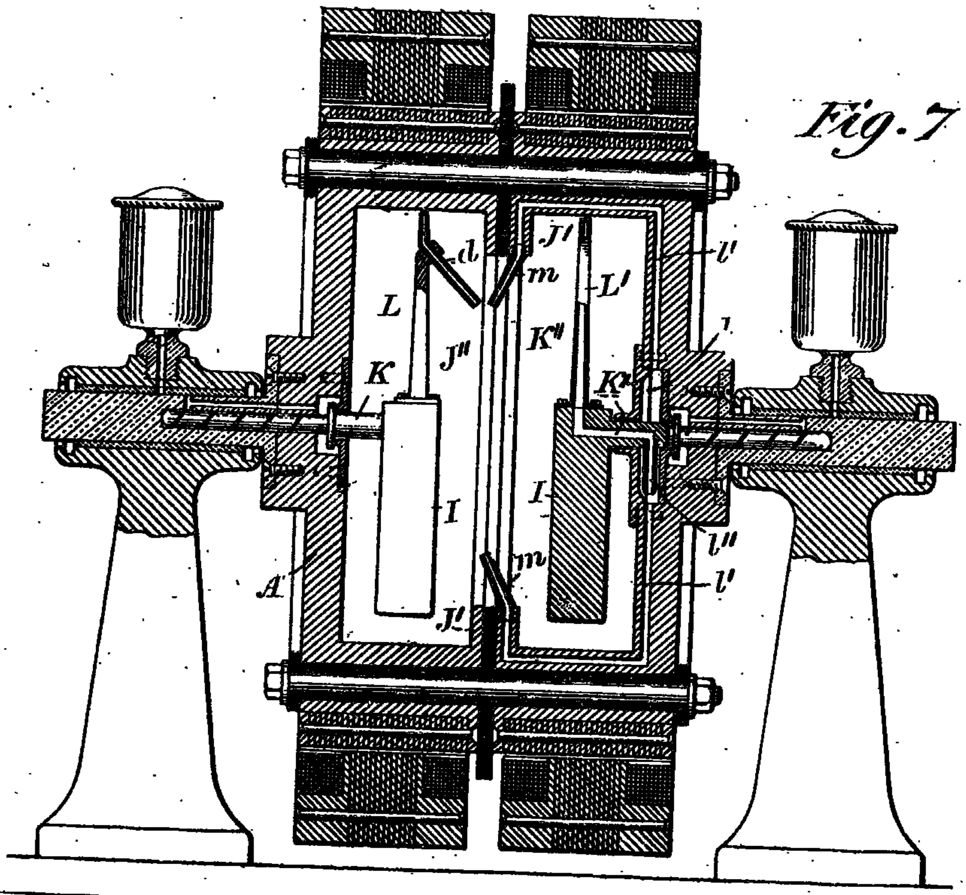

Fig. 8

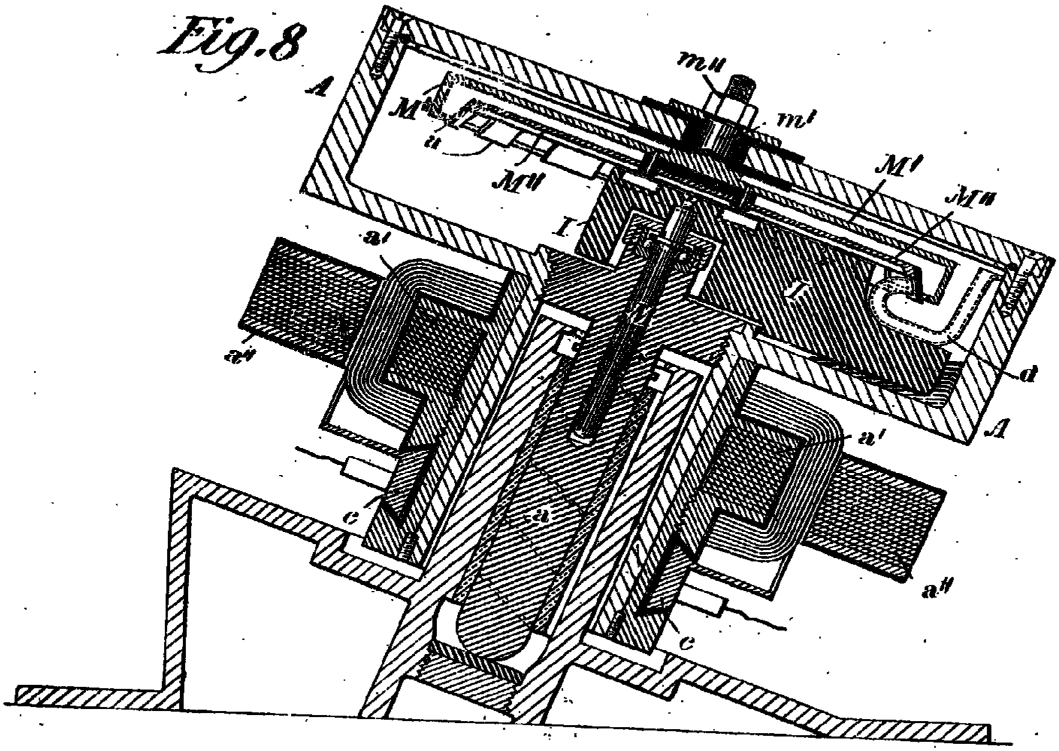

Fig. 11

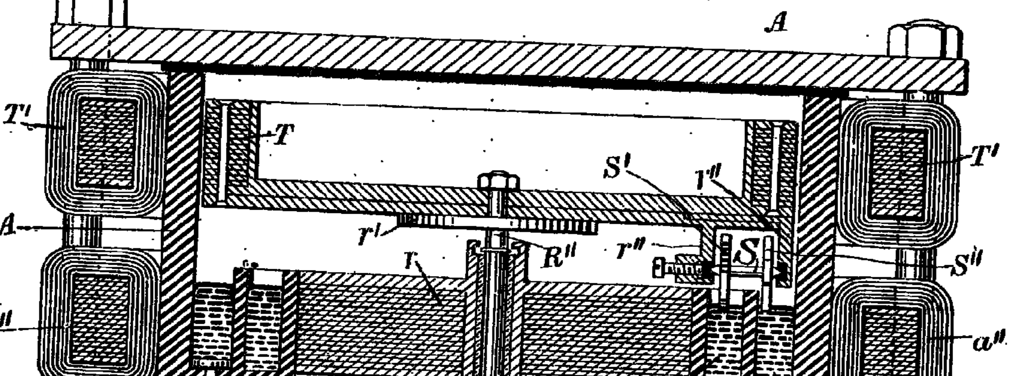

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Fig. 9

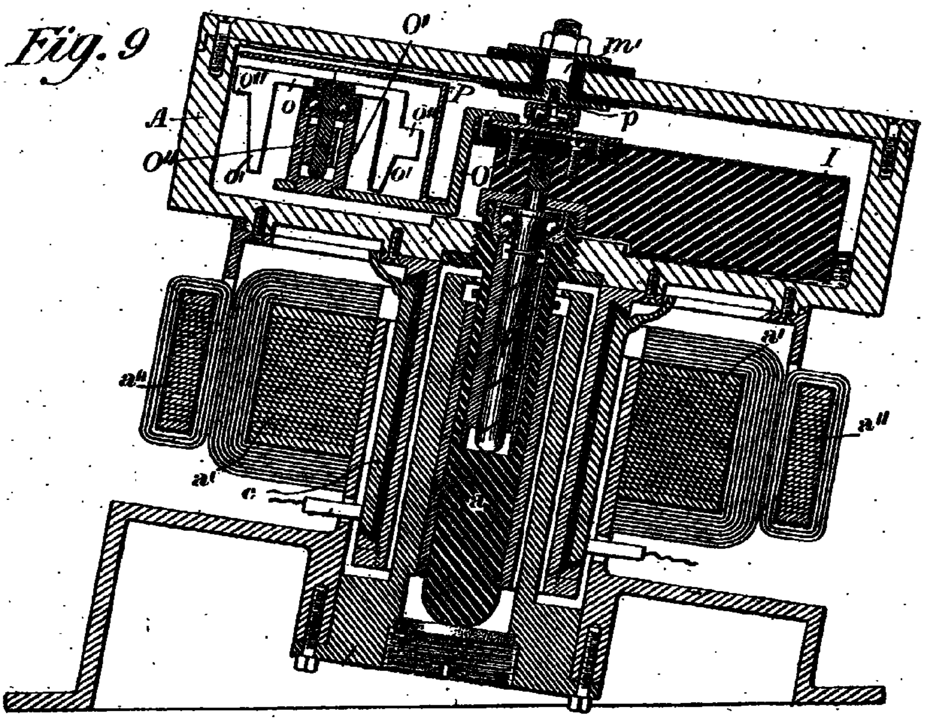
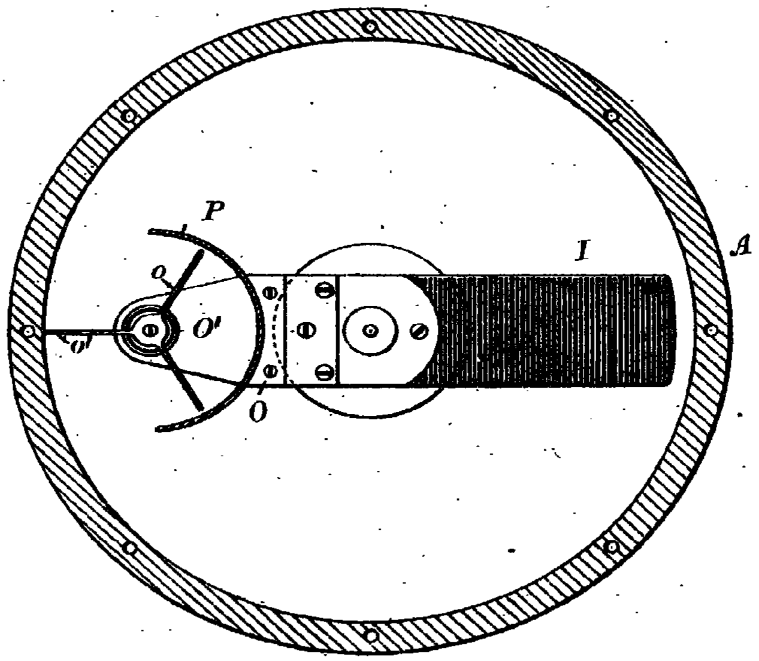


Fig. 10



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N° 26,371 A.D. 1898

(*Under International Convention.*)

Date claimed for Patent under Sect. 103 of Act, being date of first Foreign Application (in United States), *1st July, 1898*

Date of Application (in United Kingdom), 13th Dec., 1898

Complete Specification Left, 13th Dec., 1898—Accepted, 9th Dec., 1899

COMPLETE SPECIFICATION.

Improvements in the Method of and Apparatus for Controlling the Mechanism of Floating Vessels or Moving Vehicles.

I, Nikola Tesla, of 46, East Houston Street, New York, United States of America, Electrician, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The problem for which the invention forming the subject of the present application, affords a complete and practicable solution, is that of controlling from a given point the operation of the propelling engines, the steering apparatus and other mechanism carried by a moving object, such as a boat, or any floating vessel, or carriage, such as an automobile, whereby the movements and course of such body or vessel may be directed and controlled from a distance, and any device carried by the same, brought into action at any desired time.

So far as I am aware, the only attempts to solve this problem which have heretofore met with any measure of success, have been made in connection with a certain class of vessels, the machinery of which was governed by electric currents conveyed to the controlling apparatus through a flexible conductor. But this system is subject to such obvious limitations as are imposed by the length, weight and strength of the conductor which can be practically used, by the difficulty of maintaining with safety a high speed of the vessel or changing the direction of movement of the same with the desired rapidity, by the necessity for effecting the control from a point which is practically fixed, and by many well-understood drawbacks inseparably connected with such a system.

The plan which I have perfected involves none of these objections for I am enabled by the use of my invention to employ any means of propulsion, to impart to the moving body or vessel the highest possible speed, to control the operation of its machinery and to direct its movements from whether a fixed point or from a body moving and changing its direction however rapidly, and to maintain this control over great distances, without any artificial connections between the vessel and the apparatus governing its movements, and without such restrictions as these must necessarily impose.

In a broad sense, then, my invention differs from all of those systems which provide for the control of the mechanism carried by a moving object and

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governing its motion, in that I require no intermediate wires, cables or other form of electrical or mechanical connection with the object save the natural media in space. I accomplish, nevertheless, similar results and in a much more practicable manner by producing waves, impulses or radiations which are received through the earth, water or atmosphere by suitable apparatus on the moving body and cause the desired actions, so long as the body remains within the active region or effective range of such currents, waves, impulses or radiations.

The many and different requirements of the object here contemplated, involving peculiar means for transmitting to a considerable distance an influence capable of causing, in a positive and reliable manner, these actions, necessitated the designing of devices and apparatus of a novel kind in order to utilize to the best advantage various facts or results which, either through my own investigations or those of others, have been rendered practically available.

As to that part of my invention which involves the production of suitable waves or variations and the conveying of the same to a remote receiving apparatus capable of being operated or controlled by their influence, it may be carried out in various ways which are at the present time more or less understood. For example, I may pass through a conducting path, preferably enclosing a large area, a rapidly varying current and by electro-magnetic induction of the same, affect a circuit carried by the moving body. In this case the action at a given distance will be the stronger the larger the area enclosed by the conductor and the greater the rate of change of the current. If the latter were generated in the ordinary ways, the rate of change, and consequently the distance at which the action would be practically available for the present purpose, would be very small; but by adopting such means as I have devised, that is—either by passing through the conducting path currents of a specially designed high frequency alternator or better still, those of a strongly charged condenser, a very high rate of change may be obtained, and the effective range of the influence thus extended over a vast area, and by carefully adjusting the circuit on the moving body so as to be in exact electro-magnetic synchronism with the primary disturbances, this influence may be utilized at great distances.

Another way to carry out my invention is to direct the currents or discharges of a high frequency machine or condenser through a circuit, one terminal of which is connected directly or inductively with the ground and the other to a body, preferably of large surface and at an elevation. In this case of the circuit on the moving body be similarly arranged or connected, differences of potential on the terminals of the circuit either by conduction or electrostatic induction are produced, and the same object is attained. Again, to secure the best action, the receiving circuit should be adjusted so as to be in electro-magnetic synchronism with the primary source as before, but in this instance it will be understood by those skilled in the art that, if the number of vibrations per unit of time be the same, the circuit should now have a length of conductor only one half of that used in the former case.

Still another way is to pass the currents simply through the ground by connecting both the terminals of the source of high frequency currents to earth at different and remote points and to utilize the currents spreading through the ground for effecting a receiving circuit properly placed and adjusted. Again, in this instance, if only one of the terminals of the receiving circuit be connected to the ground—the other terminal being insulated—the adjustment as to synchronism with the source will require that under otherwise equal conditions the length of wire be half of that which would be used if both the terminals be connected or, generally, if the circuit be in the form of a closed loop or coil. Obviously also, in the latter case, the relative position of the receiving and transmitting circuits is of importance, whereas, if the circuit be of the former kind, that is, open, the relative position of the circuits is, as a rule, of little or no consequence.

Finally, I may avail myself, in carrying out my invention, of electrical oscillations which do not follow any particular conducting path, but propagate in straight lines through space, of rays, waves, pulses or disturbances of any kind, capable of bringing the mechanism of the moving body into action from a distance and at the will of the operator by their effect upon suitable controlling devices.

In the following detailed description I shall confine myself to an explanation of that method and apparatus only which I have found to be the most practical and effectual, but obviously, my invention in its broad features is not limited to the special mode and appliances which I have devised and shall here describe.

In any event, that is to say—whichever of the above or similar plans I may adopt—and, particularly, when the influence exerted from a distance upon the receiving circuit be too small to directly and reliably affect and actuate the controlling apparatus, I employ auxiliary sensitive relays or, generally speaking, means capable of being brought into action by the feeblest influences, in order to effect the control of the movements of the distant body with the least possible expenditure of energy and at the greatest practicable distance, thus extending the range and usefulness of my invention.

A great variety of electrical and other devices, more or less suitable for the purpose of detecting and utilizing feeble actions, are now well known to scientific men and artisans, and need not be all enumerated here. Confining myself merely to the electrical as the most practicable of such means, and referring only to those which, while not the most sensitive, are, perhaps, more readily available, from the more general knowledge which exists regarding them, I may state that a contrivance may be used which has long been known and used as a lightning arrester, in connection with telephone switchboards for operating annunciators and like devices, comprises a battery, the poles of which are connected to two conducting terminals separated by a minute thickness of dielectric. The electro-motive force of the battery should be such as to strain the thin dielectric layer very nearly to the point of breaking down, in order to increase the sensitiveness. When an electrical disturbance reaches a circuit so arranged and adjusted, additional strain is put upon the insulating film which gives way and allows the passage of a current, which can be utilized to operate any form of circuit controlling apparatus.

Again, another contrivance capable of being utilized in detecting feeble electrical effects, consists of two conducting plates or terminals which have preferably wires of some length attached to them and are bridged by a mass of minute particles of metal or other conducting material. Normally these particles, lying loose, do not connect the metal plates, but under the influence of an electrical disturbance produced at a distance, evidently owing to electrostatic attraction, they are pressed firmly against each other, thus establishing a good electrical connection between the two terminals. This change of state may be made use of in number of ways for the above purpose.

Still another modified device which may be said to embody the features of both the former, is obtained by connecting the two conducting plates or terminals, above referred to, permanently with the poles of a battery which should be of very constant electro-motive force. In this arrangement a distant electrical disturbance produces a two-fold effect on the conducting particles and insulating films between them. The former are brought nearer to each other in consequence of the sudden increase of electrostatic attraction, and the latter, owing to this, as well as by being reduced in thickness or in number, are subjected to a much greater strain which they are unable to withstand.

It will be obviously noted from the preceding that, which ever of these or similar contrivances be used, the sensitiveness and, what is often still more important, the reliability of operation is very materially increased by a close adjustment of the periods of vibration of the transmitting and receiving circuits, and, although such adjustment is in many cases unnecessary for the successful carrying out of my invention, I nevertheless make it a rule to bestow upon this feature the greatest possible care, not only because of the above mentioned advantages which are secured by the observance of the most favorable conditions in this respect, but also, and chiefly, with the object of preventing the receiving circuit from being affected by waves or disturbances emanating from sources not under the control of the operator. The narrower the range of vibrations which are still capable of perceptibly affecting the receiving circuit, the safer will the latter be against extraneous disturbances. To secure the best result it is necessary, as is well known to experts, to construct the receiving circuit, or that part of the same in which the vibration chiefly occurs, so that it will have the highest possible self-induction and at the same time the least possible resistance. In this manner I have demonstrated the practicability of providing a great number of such receiving circuits—fifty or a hundred or more—each of which may be called up or brought into action whenever desired, without the others being interfered with. This result makes it possible for one operator to direct, simultaneously, the movements of a number of bodies, as well as to control the action of a number of devices located on the same body, each of which may have a distinct duty to fulfil. In the following description, however, I shall show a still further development in this direction, namely, how, by making use of merely one receiving circuit, a great variety of devices may be actuated and any number of different functions performed at the will and command of the distant operator.

It should be stated in advance, in regard to the sensitive devices above mentioned, which may be broadly considered as belonging to one class—inasmuch as the operation of all of them involves the breaking down of a minute thickness of highly strained dielectric—that it is necessary to make some provision for automatically restoring to the dielectric its original, unimpaired insulating qualities, in order to enable the device to be used in successive operations.

This is usually accomplished by a gentle tapping or vibration of the electrodes or particles, or continuous rotation of the same, but in long experience with many forms of these devices I have found that such procedures, while suitable in simple and comparatively unimportant operations, as ordinary signalling, when it is merely required that the succeeding effects produced in the receiving circuit should differ in regard to their relative duration only,—in which case it is of little or no consequence if some of the individual effects be altered, or incomplete, or even entirely missed—do not yield satisfactory results in many instances, when it may be very important that the effects produced should all be exactly such as desired and that none should fail. To illustrate, let it be supposed that an official, directing the movements of a vessel in the manner described, should find it necessary to bring into action a special device on the latter, or to perform a particular operation, perhaps of vital moment, at an instant's notice and possibly when, by design or accident, the vessel itself or any mark indicating its presence is hidden from his view. In this instance a failure or defective action of any part of the apparatus might have disastrous consequences and such cases, in which the sure and timely working of the machinery is of paramount importance, may often present themselves in practice, and this consideration has impressed me with the necessity of doing away with the defects in the present devices and procedures and of producing an apparatus which, while being sensitive, will also be most reliable and positive in its action. In the arrangement hereinafter described these defects are overcome is a most satisfactory manner, enabling thousands of successive operations, in all respects alike, being performed by the controlling apparatus without a single irregularity or miss being recorded. For a better understanding of these and other details of the invention as I now carry them out, I would refer to the accompanying drawings, in which:

Figure 1 is a plan view of a vessel and mechanism within the same.

Figure 2 is a longitudinal section of the same showing the interior mechanism in side elevation.

Figure 3 is a plan view, partially diagrammatical, of the vessel, apparatus and circuit connections of the same.

Figure 4 is a plan view on an enlarged scale of a portion of the controlling mechanism.

Figure 5 is an end view of the same.

Figure 6 shows the same mechanism in side elevation.

Figure 7 is a side view of a detail of the mechanism.

Figure 8 is a central sectional view on a larger scale of a sensitive device forming part of the receiving circuit.

Figure 9 is a diagrammatic illustration of the system in its preferred form.

Figure 10 is a view of the various mechanism employed but on a larger scale and leaving out or indicating conventionally certain parts of well understood character.

Referring to Figure 1 and Figure 2, A designates any type of vessel or vehicle which is capable of being propelled and directed, such as a boat, or a carriage such as an automobile. It may be designed to carry, in a suitable compartment B, objects of any kind, according to the nature of the uses to which it is to be applied. The vessel, in this instance, a boat, is provided with suitable propelling machinery which is shown as comprising a screw propellor C, secured to the shaft of an electro-magnetic motor D, which derives its power from storage batteries E, E, E, E.

In addition to the propelling engine or motor, the boat carries also a smaller steering motor F, the shaft of which is extended beyond its bearings and provided with a worm which meshes with a toothed wheel G. This latter is fixed to a sleeve *b*, freely movable on a vertical rod H, and is rotated in one or the other direction according to the direction of rotation of the motor F.

The sleeve *b* on rod H is in gear through the cog wheels H^1 and H^{11} with a spindle G^1 mounted in vertical bearings at the stem of the boat and carrying the rudder F^1.

The apparatus, by means of which the operation of both the propelling and steering mechanism is controlled, involves, primarily, a receiving circuit which, for reasons before stated, is preferably both adjusted and rendered sensitive to the influence of waves or impulses emanating from a remote source, the adjustment being so that the period of oscillation of the circuit is either the same as that of the source or a harmonic thereof.

The receiving circuit proper, diagrammatically shown in Figures 3 and 10, comprises a terminal E^1, conductor C^1, a sensitive device A^1 and a conductor A^{11} leading to the ground, conveniently through a connection to the metal keel B^1 of the vessel.

The terminal E^1 should present a larger conducting surface and should be supported as high as practicable on a standard D^1, which is shown as broken in Figure 2, but such provisions are not always necessary. It is important to insulate very well the conductor C^1, in whatever manner it be supported.

The circuit or path just referred to forms also a part of a local circuit, which latter includes a relay magnet *a* and a battery a^1, the electro-motive force of which is, as before explained, so determined that although the dielectric layers in the sensitive device A^1 are subjected to a great strain, yet normally they withstand the strain and no appreciable current flows through the local circuit. But when an electrical disturbance reaches the circuit, the dielectric films are broken down, the resistance of the device A^1 is suddenly and greatly diminished and a current traverses the relay magnet *a*.

The particular sensitive device employed is shown in general views and in detail in Figures 4, 6, 7 and 8. It consists of a metal cylinder *c* with insulating heads c^1, through which passes a central metallic rod c^{11}. A small quantity of grains d of conducting material, such as an oxidized metal is placed in the cylinder.

A metallic strip d^1, secured to an inclined post d^{11} bears against the side of the cylinder c, connecting it with the conductor C^1 forming one part of the circuit. The central rod c^{11} is connected to the frame of the instrument and so to the other part of the circuit through the forked metal arm e, the ends of which are fastened with two nuts to the projecting ends of the rod, by which means the cylinder c is supported.

In order to interrupt the flow of battery current which is started through the action of the sensitive device A^1 special means are provided, which are as follows: The armature e^1 of the magnet a, when attracted by the latter, closes a circuit containing a battery b^1 and magnet f. The armature lever f^1 of this magnet is fixed to a rock shaft f^{11}, to which is secured an anchor escapement g which controls the movements of a spindle g^1 driven by a clock train K.

The spindle g^1 has fixed to it a disk g^{11} with four pins h^{11}, so that for each oscillation of the escapement g the spindle g^1 is turned through one quarter of a revolution.

One of the spindles in the clock train, as h, is geared so as to make one half of a revolution for each quarter revolution of the spindle g^1. The end of the former spindle extends through the side of the frame and carries an eccentric cylinder h^1 which passes through a slot in a lever h^{11} pivoted to the side of the frame.

The forked arm e which supports the cylinder c is pivoted to the end of eccentric h^1, and the eccentric and said arm are connected by a spiral spring i.

Two pins i^1, i^1, extend out from the lever h^{11}, and one of these is always in the path of a projection on arm e. They operate to prevent the turning of cylinder c with the spindle h and the eccentric. It will be evident that a half revolution of the spindle h will wind up the spring i and at the same time raise or lower the lever h^{11}, and these parts are so arranged that just before the half revolution of the spindle is completed the pin i^1, in engagement with projection or stop pin p, is withdrawn from its path and the cylinder c, obeying the force of the spring i, is suddenly turned end for end, its motion being checked by the other pin i^1.

The adjustment relatively to armature f^1 or magnet f is furthermore so made, that the pin i^1 is withdrawn at the moment when the armature has nearly reached its extreme position in its approach towards the magnet, that is, when the lever l which carries the armature f^1, almost touches the lower one of the two stops $s\,s$, Figure 5, which limits its motion in both directions.

The arrangement just described has been the result of long experimenting with the object of overcoming certain defects in devices of this kind, to which reference has been made before. These defects I have found to be due to many causes as, the unequal size, weight and shape of the grains, the unequal pressure which results from this and from the manner in which the grains are usually agitated, the lack of uniformity in the conductivity of the surface of the particles owing to the varying thickness of the superficial oxidized layer, the varying condition of the gas or atmosphere in which the particles are immersed and to certain deficiences, well known to experts, of the transmitting apparatus as heretofore employed, which are in a large measure reduced by the use of my improved high frequency coils. To do away with the defects in the sensitive device, I prepare the particles so that they will be in all respects as nearly alike as possible. They are manufactured by a special tool insuring their equality in size, weight and shape, and are then uniformly oxidized by placing them for a given time in an acid solution of predetermined strength. This secures equal conductivity of their surfaces and stops their further deterioration, thus preventing a change in the character of the gas in the space in which they are inclosed. I prefer not to rarefy the atmosphere within the sensitive device, as this has the effect of rendering the former less constant in regard to its dielectric properties, but merely secure an air-tight inclosure of the particles and rigorous absence of moisture, which is fatal to satisfactory working.

The normal position of the cylinder c is vertical and when turned in the manner described, the grains in it are simply shifted from one end to the other. But inasmuch as they always fall through the same space and are subjected to the same agitation, they are brought, after each operation of the relay, to precisely the same electrical condition, and offer the same resistance to the flow of the battery current until another impulse from afar reaches the receiving circuit.

The relay magnet a should be of such character as to respond to a very weak current and yet be positive in its action. To insure the retraction of its armature e^1 after the current has been established through the magnet f and interrupted by the inversion of the sensitive device c, a light rod k is supported in guides on the frame in position to be lifted by an extension k^1 of the armature lever l and to raise slightly the armature e^1. As a feeble current may normally flow through the sensitive device and the relay magnet a, which would be sufficient to hold, though not draw the armature down, it is well to observe this precaution.

The operation of the relay magnet a and the consequent operation of the electro-magnet f, as above described, are utilized to control the operation of the propelling engine and the steering apparatus in the following manner;

On the spindle g^1 which carries the escapement disc g^{11}, Figure 4 and Figure 6, is a cylinder j of insulating material with a conducting plate or head at each end. From these two heads, respectively, contact plates or segments $j^1 j^{11}$, extend on diametrically opposite sides of the cylinder. The plate j^{11} is in electrical connection with the frame of the instrument through the head from which it extends, while insulated strips or brushes J J^1 bear upon the free end or head of the cylinder and the periphery of the same respectively. Three terminals are thus provided, one always in connection with plate j^1, the other always in connection with the plate j^{11}, and the third adapted to rest on the strips j^1 and j^{11} in succession or upon the intermediate insulating spaces, according to the position in which the commutator is brought by the clock train and the anchor escapement g.

K^1 K^{11}, Figures 1, 3 and 10, are two relay magnets, conveniently placed in the rear of the propelling engine. One terminal of a battery k^{11} is connected to one end of each of the relay coils; the opposite terminal to the brush J^1, and the opposite ends of the relay coils to the brush J, and to the frame of the instrument respectively. As a consequence of this arrangement either the relay K^1 or K^{11} will be energized, as the brush J^1 bears upon the plate j^1 or j^{11} respectively, or both relays will be inactive while the brush J^1 bears upon an insulating space between the plates j^1 and j^{11}.

While one relay, as K^1, is energized, its armature closes a circuit through the motor F, which is rotated in a direction to throw the rudder to port. On the other hand, when relay K^{11} is active, another circuit through the motor F is closed which reverses its direction of rotation and shifts the rudder to starboard. These circuits however, are at the same time utilized for other purposes, and their course is, in part, through apparatus which I shall describe before tracing their course.

The fixed rod H carries an insulating disc or head L, Figure 2, to the under side of which are secured six brushes, 1, 2, 3, 4, 5, and 6, Figure 3. The sleeve b which surrounds the rod and is turned by the steering motor F carries a disc L^1, upon the upper face of which are two concentric circles of conducting contact plates. Brushes 1, 2, 3 and 4 bear upon the inner circle of contacts, while the brushes 5 and 6 bear upon the outer circle of contacts.

The outer circle of contacts comprises two long plates 7 and 8 on opposite sides of the disc, and a series of shorter plates, 9, 10, 11, 12, 13 and 14 in the front and rear. Flexible conductors l^1, l^{11} connect the plates 7 and 8 with the terminals of the propelling motor D, and the poles of the main battery E are connected to the brushes 5 and 6 respectively, so that, while the rudder is straight or turned up to a certain angle to either side, the current is conveyed through the brushes 5 and 6 and segments 7 and 8 to the propelling motor D.

The steering motor F is also driven by current taken from the main battery E in the following manner. A conductor 15 from one pole of the battery leads to one of the commutator brushes, and from the other brush runs a conductor 16, to one of the contacts of each relay $K^1 K^{11}$. When one of these relays, as K^{11}, is active, it continues this circuit through a wire 19, through one field coil or set of coils on the motor F, and thence to the brush 1. In a similar manner, when the other relay K^1 is active, the circuit is continued from wire 18 through a wire 20, the second or reversing set of fluid coils and to brush 2.

Both brushes 1 and 2, at all times when the rudder is not turned more than about forty-five degrees to one side, are in contact with a long conducting plate 21, and one brush in any position of the rudder is always in contact with said plate, and the latter is connected by a flexible conductor 22 with the opposite pole of the main battery. Hence the motor F may always be caused to rotate in one direction, whatever may be the position of the rudder, and may be caused to rotate in either direction whenever the position of the rudder is less than a predetermined angle, conveniently forty-five degrees from the centre position.

In order, however, to prevent the rudder from being turned too far in either direction, the isolated plate 23 is used. Any movement of the rudder beyond a predetermined limit brings this plate under one or the other of the brushes 1, 2, and breaks the circuit of motor F, so that the rudder can be driven no further in that direction, but, as will be understood, the apparatus is in condition to turn the rudder over to the other side.

In like manner the circuit of the propelling motor D is controlled through brushes 5 and 6 and the segments on the outer circle of contacts of head L. If the short segments on either side of the circle are insulated the motor D will be stopped whenever one of the brushes 5 or 6 passes onto one of them from the larger segments 7, 8.

It is important to add that on all contact points where a break occurs, provision should be made to overcome the sparking and prevent the oscillation of electrical charges in the circuits, as such sparks and oscillations may affect the sensitive device. It is this consideration chiefly, which makes it advisable to use the two relays $K^1 K^{11}$ which otherwise might be dispensed with. They should be also placed as far as practicable from the sensitive device in order to guard the latter against any action of strong varying currents.

In addition to the mechanism described the vessel may carry any other devices or apparatus as might be required for accomplishing any special object of more or less importance. By way of illustration, a small motor m is shown (Figures 1 and 3), which conveniently serves for a number of purposes. This motor is shown connected in series with the armature of the steering motor F, so that whenever either one of the circuits of the latter is closed through relays $K^1 K^{11}$, the motor m is likewise rotated, but in all cases in the same direction. Its rotation is opposed by a spring m^1 so that in normal operation, owing to the fact that the circuits of motor F are closed but a short time, the lever m^{11} which is fastened to one of the wheels of clockwork M, with which the armature of the motor is geared, will move but a short distance, and upon cessation of the current return to a stop P. But if the circuits of the motor F are closed and opened rapidly in succession, which operation leaves the rudder unaffected, then the lever m^{11} is moved to a greater angle, coming in contact with a metal plate n, and finally, if desired, with a post n^1.

Upon the lever m^{11} coming in contact with plate n, the current of the main battery passes either through one or other or both of the lights supported on standards $q\,q$, according to the position of brushes 3 and 4 relatively to the insulating segment 23. But since the head L¹ carrying the segments is geared to the rudder, the position of the latter is in a general way determined by observing the lights. Both of the lights may be colored, and by flashing them up whenever desired, the operator may guide at night the vessel in its course. For such purposes also the standards $r\,r$ are provided, which should be painted in lively colors so as to be visible by day at great distances.

By opening and closing the circuits of motor F a greater number of times, preferably determined beforehand, the lever m^{11} is brought in contact with post n^1, thus closing the circuit of the main battery through a device o Figure 10 and bringing the latter into action at the moment desired. By similar contrivances, or such as will readily suggest themselves to mechanicians, any number of different devices may be operated.

Referring now to Figure 9, which illustrates diagrammatically the system as practised when directing the movements of a boat;

In this figure S designates any source of electrical disturbance or oscillations, the generation of which is controlled by a suitable switch contained in box T. The handle of the switch is movable in one direction only and stops on four points $t\,t^1\,u\,u^1$, so that, as the handle passes from stop to stop, oscillations are produced by the source during a very short time interval. There are thus produced four disturbances during one revolution, and the receiving circuit is affected four times, but it will be understood from the foregoing description of the controlling devices on the vessel, that the rudder will be moved twice, once to right and once to left. Now I preferably place the handle of the switch so that when it is arrested on points $t\,t^1$, that is, to the right or left of the operator, he is reminded that the vessel is being deflected to the right or left from its course, by which means the control is facilitated. The normal positions of the handle are therefore at $u\,u^1$, when the rudder is not acted upon, and it remains on the points $u\,u^1$, only so long as necessary. Since, as before stated, the working of the apparatus is very sure the operator is enabled to perform any such operations as provision is made for, without even seeing the vessel.

The manner of using the apparatus and the operation of the several instrumentalities comprising the same is, in detail as follows: Normally, the plate L¹ is turned so that brush 2 rests upon the insulated segment 23, and brush 6 upon one of the isolated short segments in the rear of the circle. Under these conditions the rudder will be turned to starboard, and the circuit of motor D interrupted between brushes 5 and 6. At the same time, only one of the circuits of motor F,—that controlled by relay K¹—is capable of being closed, since brush 2, which connects with the other, is out of contact with the long segment 21.

Assuming now that it is desired to start the vessel and direct it to a given point. The handle T is turned from its normal position on point u^1 to the point t on the switch box. This sends out an electrical disturbance which passing through the receiving circuit on the vessel, affects the sensitive device A¹ and starts the flow of current through the local circuit, including said device, the relay a and the battery a^1. This, as has been previously explained, turns the cylinder j and causes the brush J¹ to pass from insulation onto the contact j^1.

The battery k^{11}, and the latter closes that circuit of the motor F which, starting from plate 22, which is permanently connected with one pole of the main battery, is completed through the brush 1, the field of motor F, wire 19, the armature of relay K¹¹, wire 16, the motor m, the brushes and commutator of motor F, and wire 15 to the opposite terminal of the battery E. Motor F is thus set in operation to shift the rudder to starboard, but the movement of plate L^1, which follows, brings the brush 6 back onto segment 8 and closes the circuit of the propelling motor, which starts the vessel.

The motor F is permitted to run until the rudder has been turned sufficiently to steer the vessel in the desired direction, when the handle T is turned to the point *u*. This produces another action of the relay *a* and brush J^1 is shifted onto insulation and both relays K^1 and K^{11} are inactive.

The rudder remains in the position to which it has been shifted by the motor F. If it be then desired to shift it to port, or in the opposite direction to that in which it was last moved, the handle T is simply turned to point t^1 and allowed to remain there until the motor F—which is now operated by relay K^1, the circuit of which is closed by strips J^1 coming into contact with plate j^{11}—has done its work.

The movement of handle T to the next point throws out both relays K^1 and K^{11}, and the next movement causes a shifting of the rudder to port, and so on. Suppose, however, that after the rudder has been set at any angle to its middle position, it be desired to shift it still further in the same direction. In such case the handle is moved quickly over two points, so that the circuit which would move the rudder in the opposite direction is closed for too short a time interval to produce an appreciable effect, and is allowed to rest on the third point until the rudder is shifted to the desired position, when the handle is moved to the next point, which again throws out both relays K^1 and K^{11}. It will be understood that if the handle be held for a sufficiently long time upon either point *t* or t^1 the motor F will simply turn the plate L^1 in one direction or the other until the circuits of motors D and F are broken. It is furthermore evident that one relay K or K^{11} will always be operative to start the motor F.

As previously explained, the longest period of operation of which the motor F is capable under ordinary conditions of use does not permit the motor *m* to shift the arm m^{11} into contact with the plate *n*. But if the handle T be turned with a certain rapidity a series of current impulses will be directed through motor *m*, but, as these tend to rotate the motor F in opposite directions they do not sensibly affect the latter, but act to rotate the motor *m* against the force of the coiled spring.

The invention which I have described will prove useful in many ways. Vessels or vehicles of any suitable kind may be used, as life, despatch, or pilot boats or the like, or for carrying letters, packages, provisions, instruments, objects or materials of any description, for establishing communication with inaccessible regions and exploring the conditions existing in the same, for killing or capturing whales or other animals of the sea, and for many other scientific, engineering or commercial purposes.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The improvement in the art of controlling the movements and operation of a vessel or vehicle herein described, which consists in producing waves or disturbances which are conveyed to the vessel by the natural media, actuating thereby suitable apparatus on the vessel and effecting the control of the propelling engine, the steering and other mechanism by the operation of the said apparatus, as set forth.

2. The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in establishing a region of waves or disturbances, and actuating by their influence exerted at a distance the devices on such vessel or vehicle, which control the propelling, steering and other mechanism thereon, as set forth.

3. The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in establishing a region

of electrical waves or disturbances, and actuating by their influence, exerted at a distance, the devices on said vessel or vehicle, which control the propelling, steering and other mechanism thereon, as set forth.

4. The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in providing on the vessel a circuit controlling the propelling, steering and other mechanism, adjusting or rendering such circuit sensitive to waves or disturbances of a definite character, establishing a region of such waves or disturbances, and rendering by their means the controlling circuit active or inactive, as set forth.

5. The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, and mechanism thereon for propelling, steering or operating the same, and a controlling apparatus adapted to be actuated by the influence of the said waves or disturbances at a distance from the source, as set forth.

6. The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, mechanism for propelling, steering or operating the same, a circuit and means therein for controlling said mechanism, and means for rendering said circuit active or inactive through the influence of the said waves or disturbances exerted at a distance from the source, as set forth.

7. The combination with a source of electrical waves or disturbances and means for starting and stopping the same, of a vessel or vehicle, propelling and steering mechanism carried thereby, a circuit containing or connected with means for controlling the operation of said mechanism and adjusted or rendered sensitive to the waves or disturbances of the source, as set forth.

8. The combination with a source of electrical waves or disturbances, and means for starting and stopping the operation of the same, of a vessel or vehicle, propelling and steering mechanism carried thereby, local circuits controlling said mechanism, a circuit sensitive to the waves or disturbances of the source and means therein adapted to control the said local circuits, as and for the purpose set forth.

9. The sensitive device herein described comprising in construction a receptacle containing a material such as particles of oxidized metal forming a part of the circuit, and means for turning the same end for end when the material has been rendered active by the passage through it of an electric discharge, as set forth.

10. The sensitive device herein described, comprising in combination a receptacle containing a material such as particles of oxidized metal forming a part of an electric circuit, an electro-magnet in said circuit, and devices controlled thereby for turning the receptacle end for end when said magnet is energized, as set forth.

11. The sensitive device herein described, comprising in combination a receptacle containing a material such as particles of oxidized metal forming part of an electric circuit, a motor for rotating the receptacle, an electro-magnet in circuit with the material, and an escapement controlled by said magnet and adapted to permit a half revolution of the receptacle when the said magnet is energized, as set forth.

12. The combination with a movable body or vehicle, of a propelling motor, a steering motor and electrical contacts carried by a moving portion of the steering mechanism, and adapted in certain positions of the latter to interrupt the circuit of the propelling motor, a local circuit and means connected therewith for controlling the steering motor, and a circuit controlling the local circuit and means for rendering said controlling circuit sensitive to the influence of electric waves or disturbances exerted at a distance from their source, as set forth.

13. The combination with the steering motor, a local circuit for directing current through the same in opposite directions, a controlling circuit rendered

sensitive to the influence of electric waves or disturbances exerted at a distance from their source, a motor in circuit with the steering motor but adapted to run always in the same direction, and a local circuit or circuits controlled by said motor, as set forth.

Dated this 13th day of December 1898.

HASELTINE, LAKE & Co.,
45, Southampton Buildings, London, W.C.,
Agents for the Applicant.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1899.

A.D. 1898. Dec. 13. N° 26,371.
TESLA'S Complete Specification.

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SHEET 1.

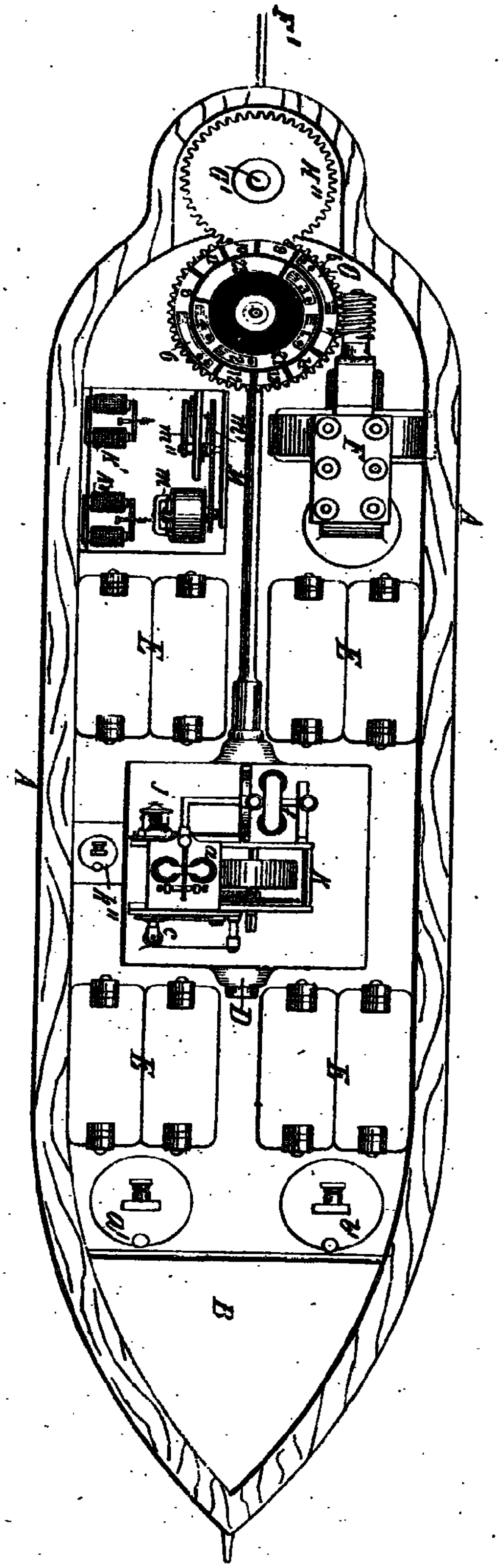

Fig. 1

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Fig. 2

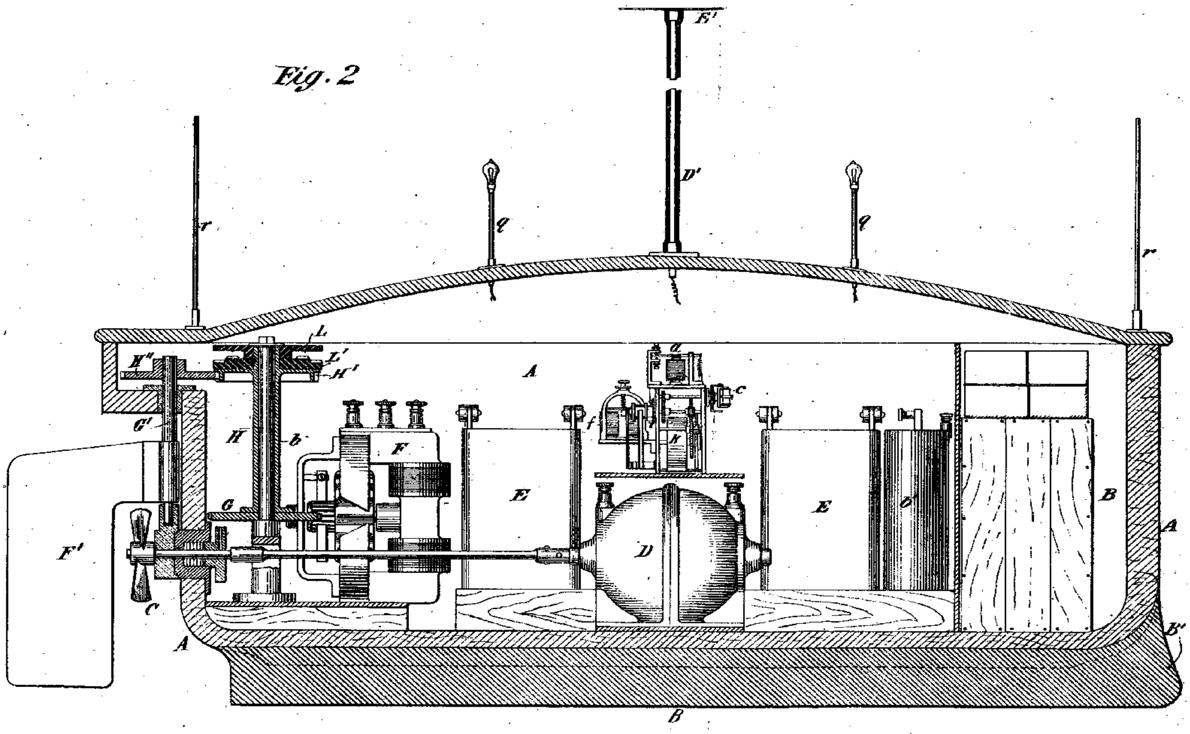

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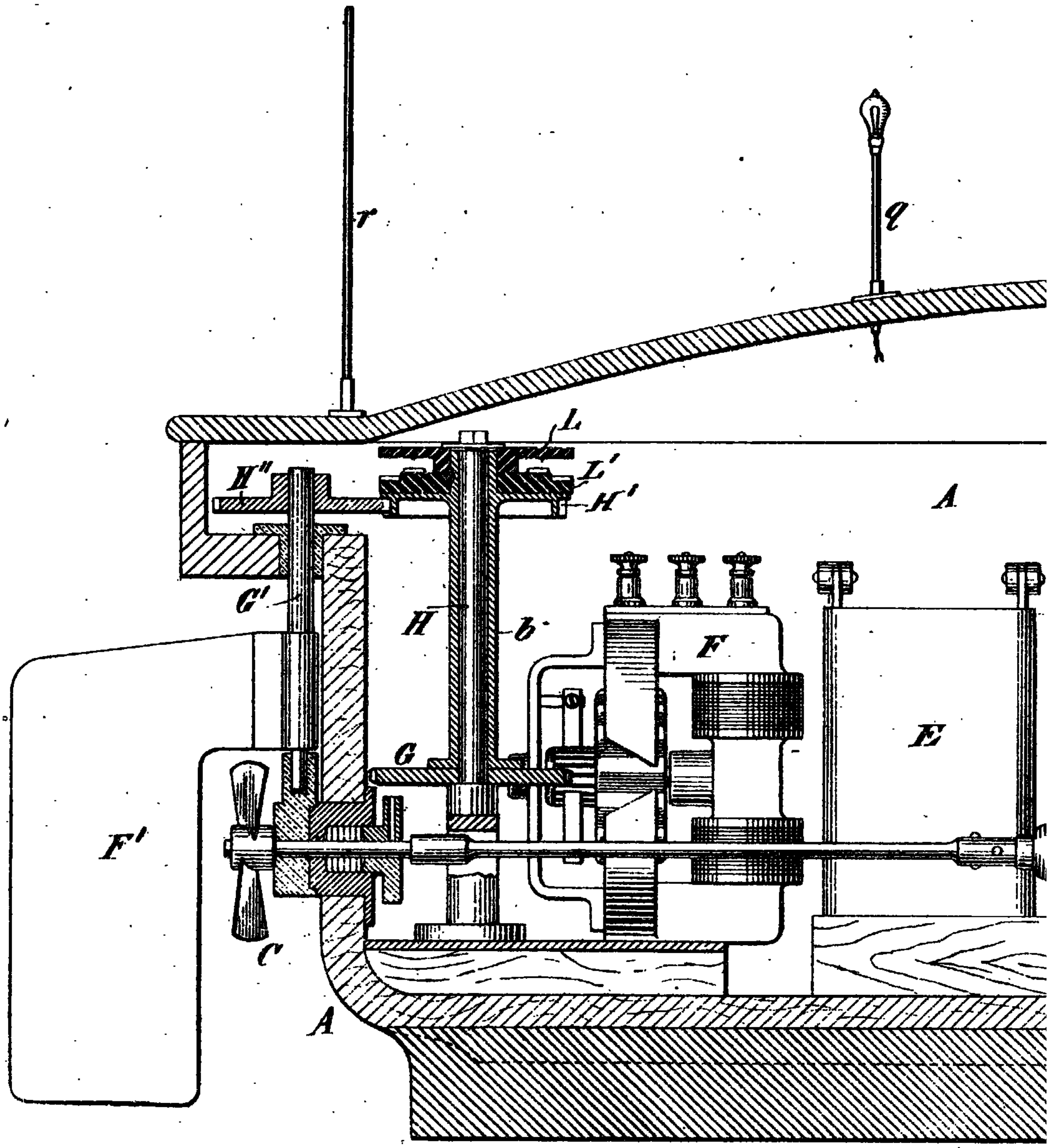
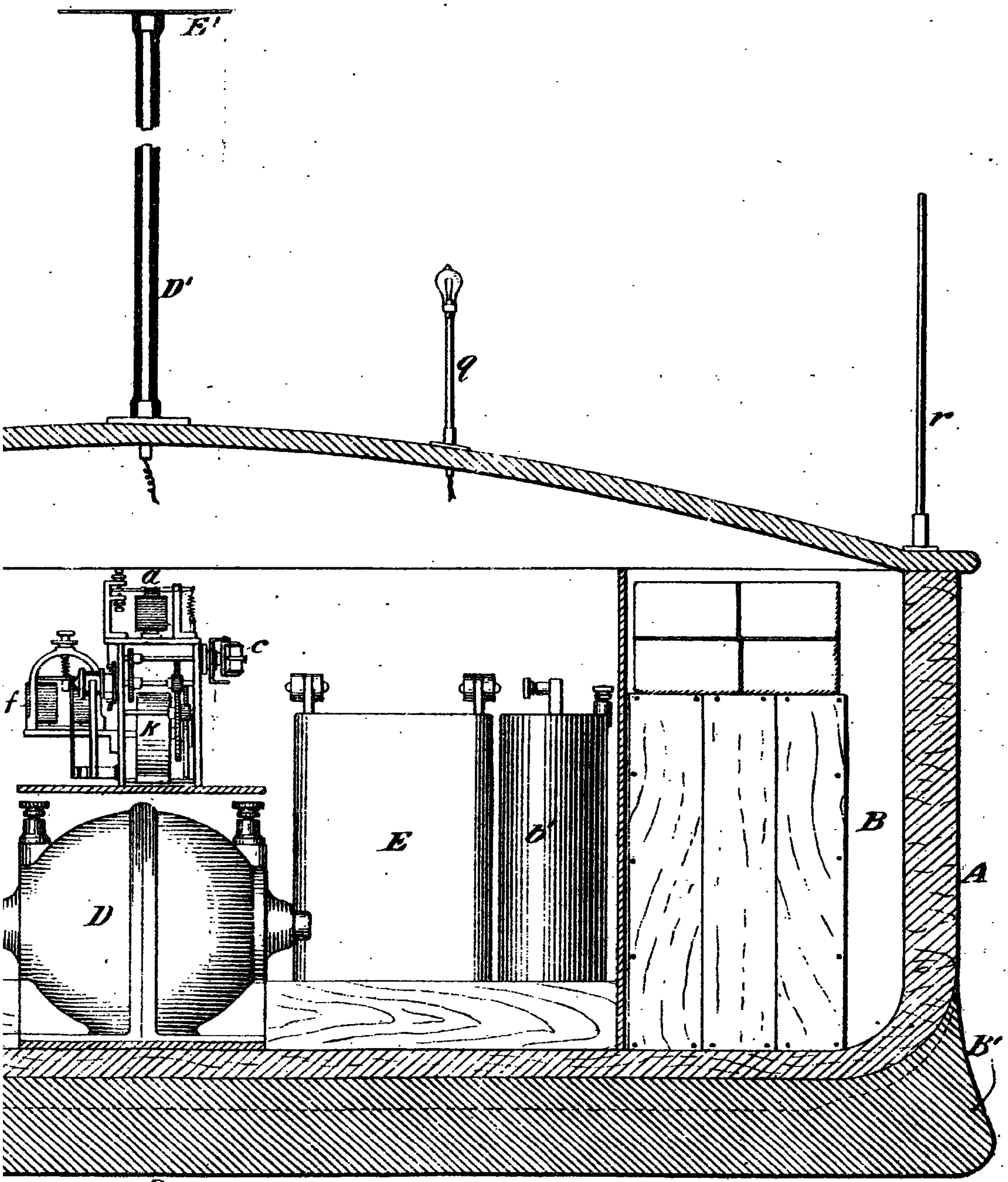
Fig. 2





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A.D. 1898. Dec. 13. Nº 26,371.
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Fig. 3

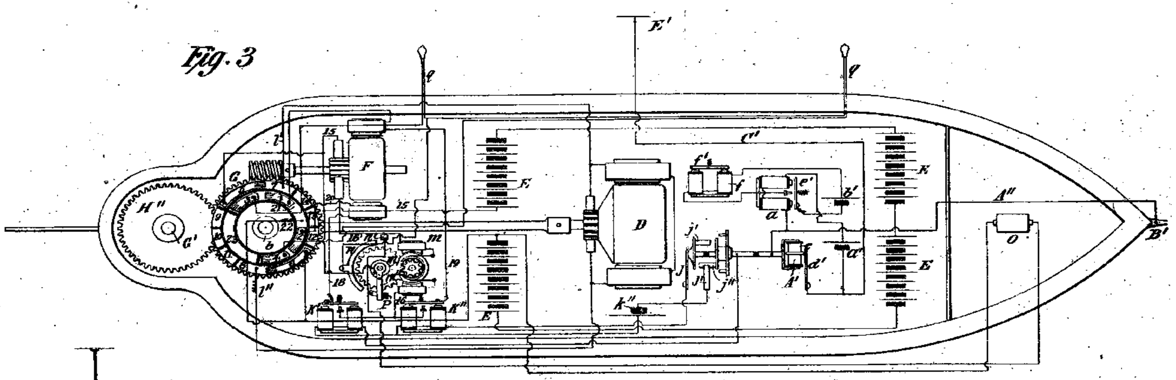

Fig. 9

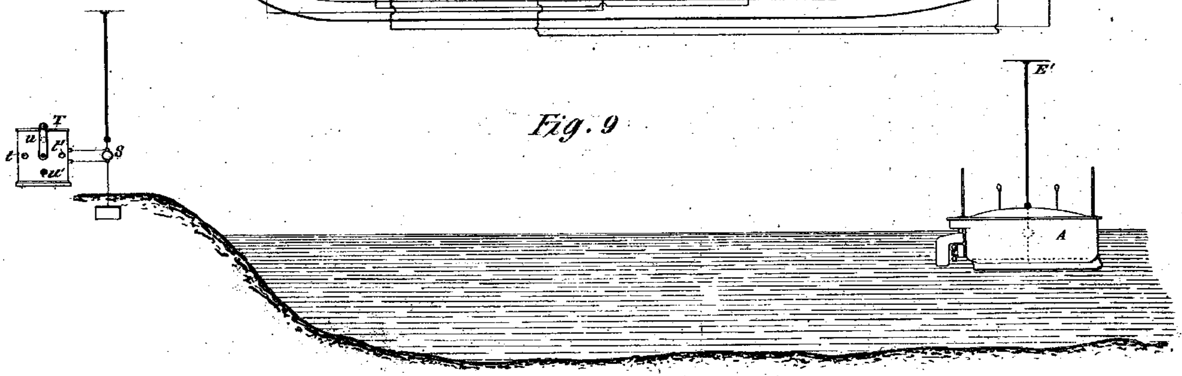

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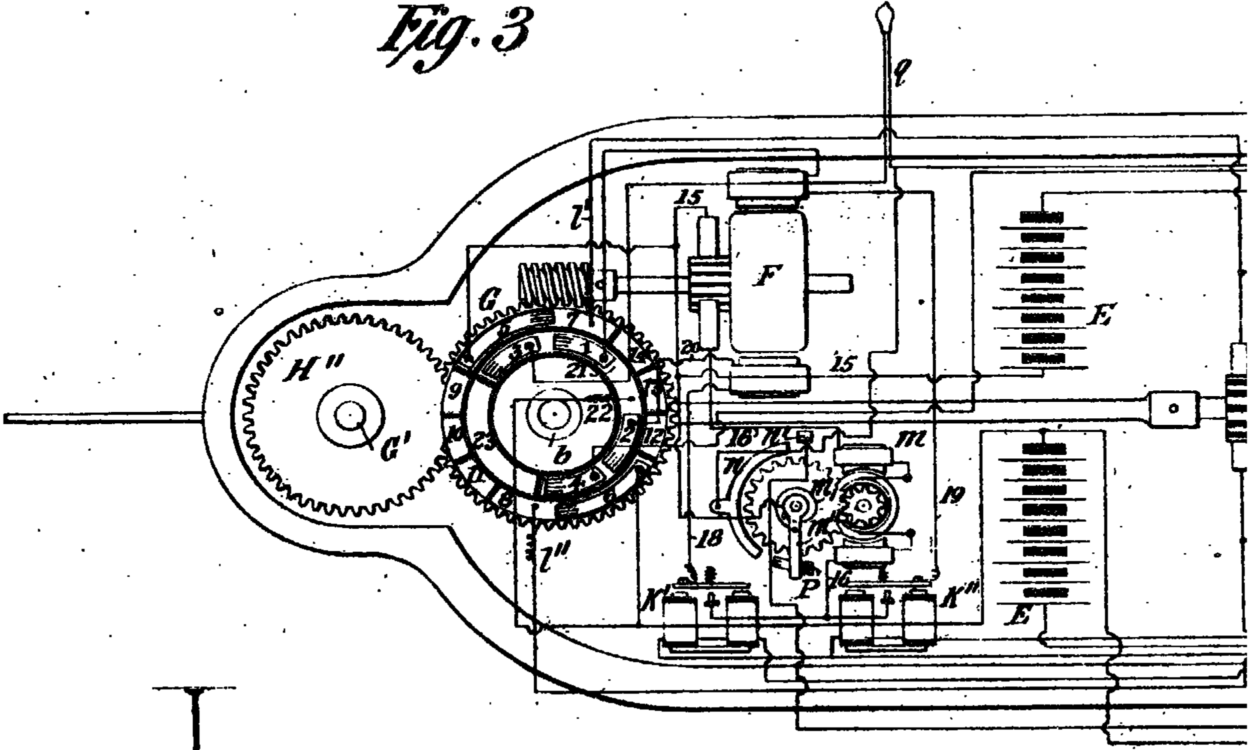
Fig. 3



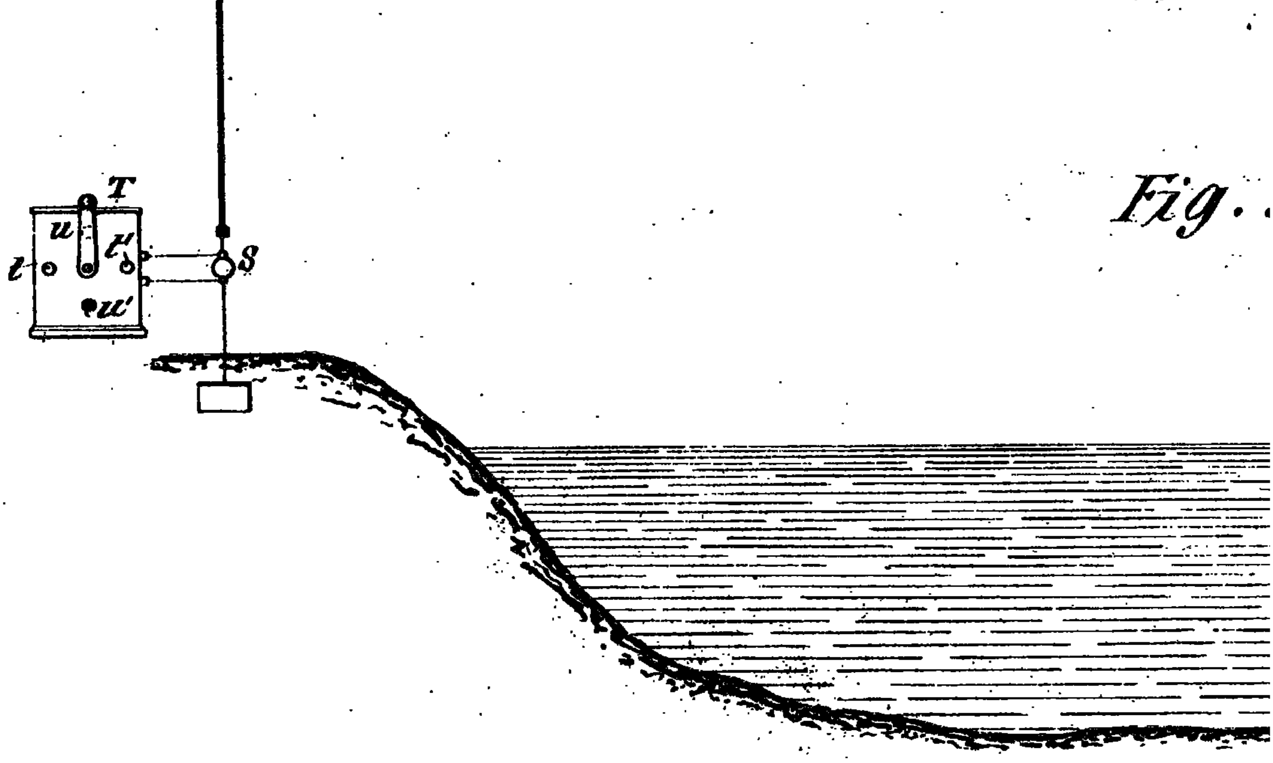
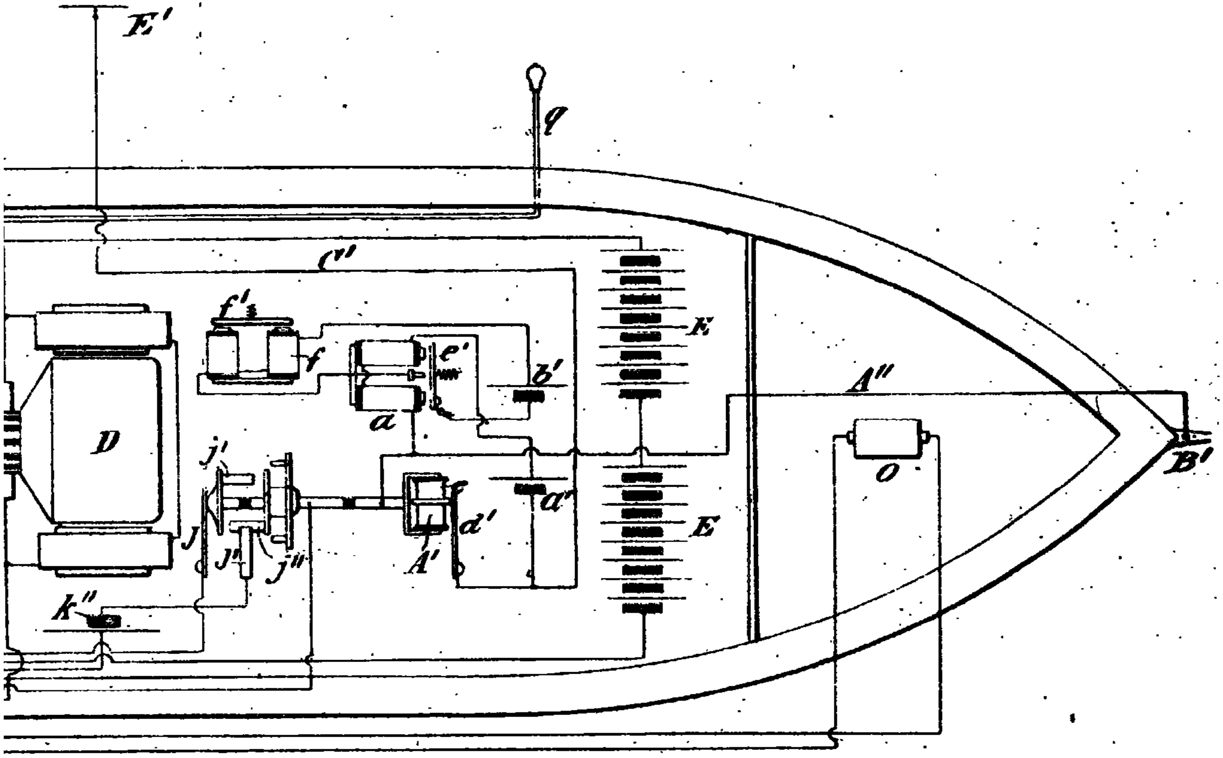


Fig.



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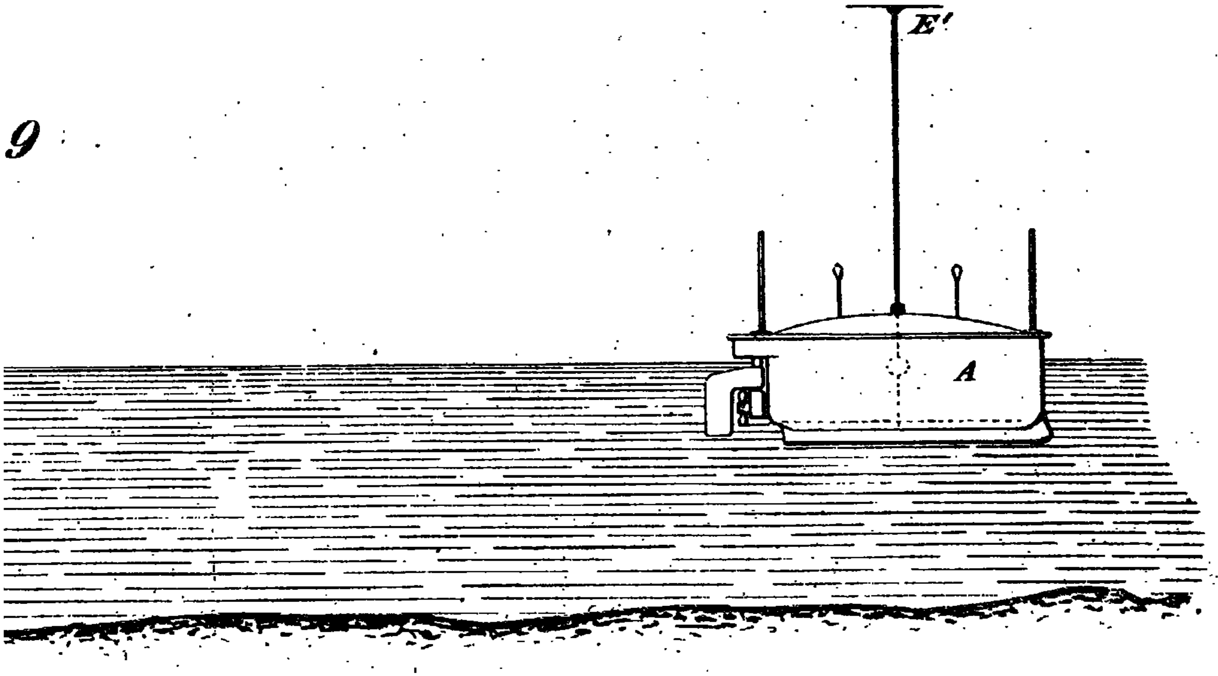

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Fig. 4.

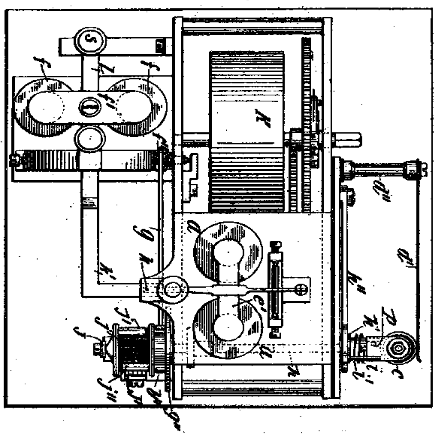

Fig. 7.

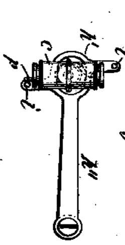

Fig. 8.

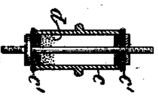

Fig. 5.

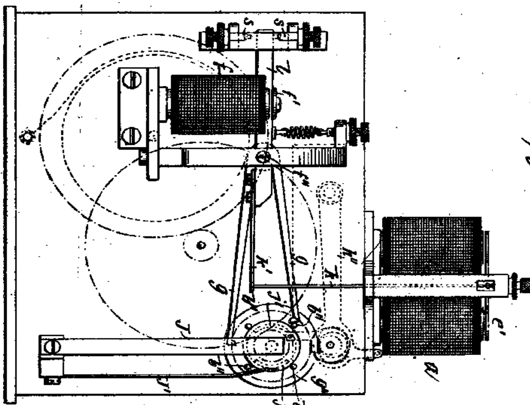

Fig. 6.

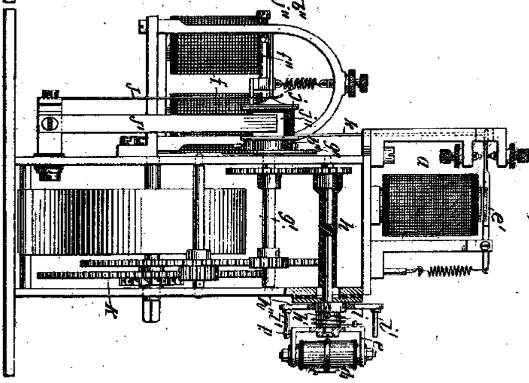

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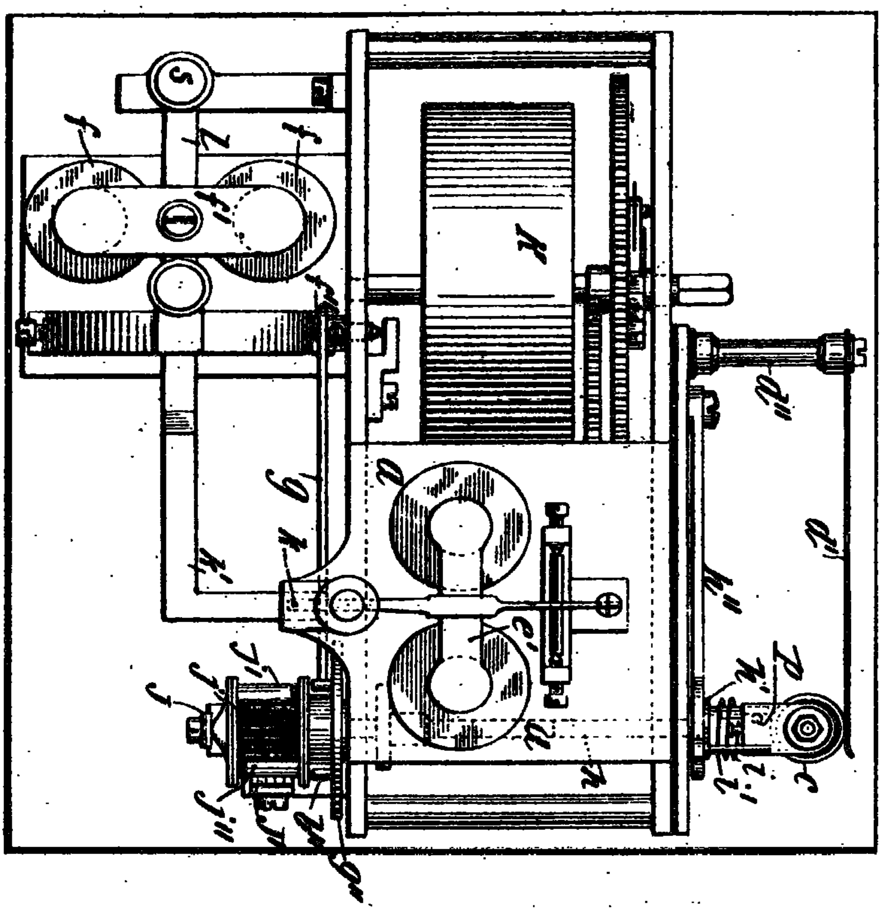
Fig. 4.



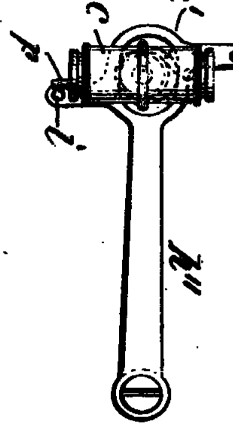


Fig. 7.

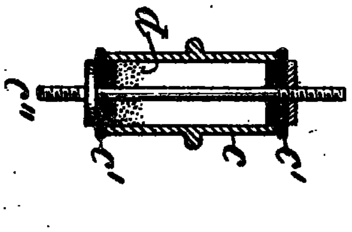


Fig. 8.

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SHEET 4.

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Fig. 5

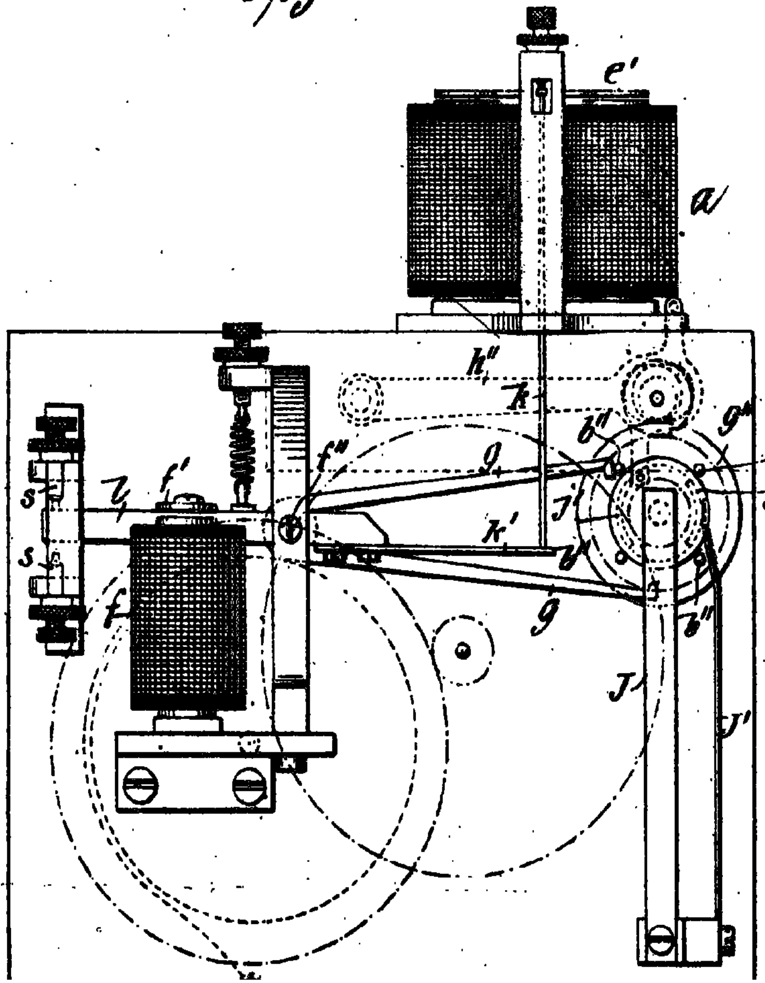
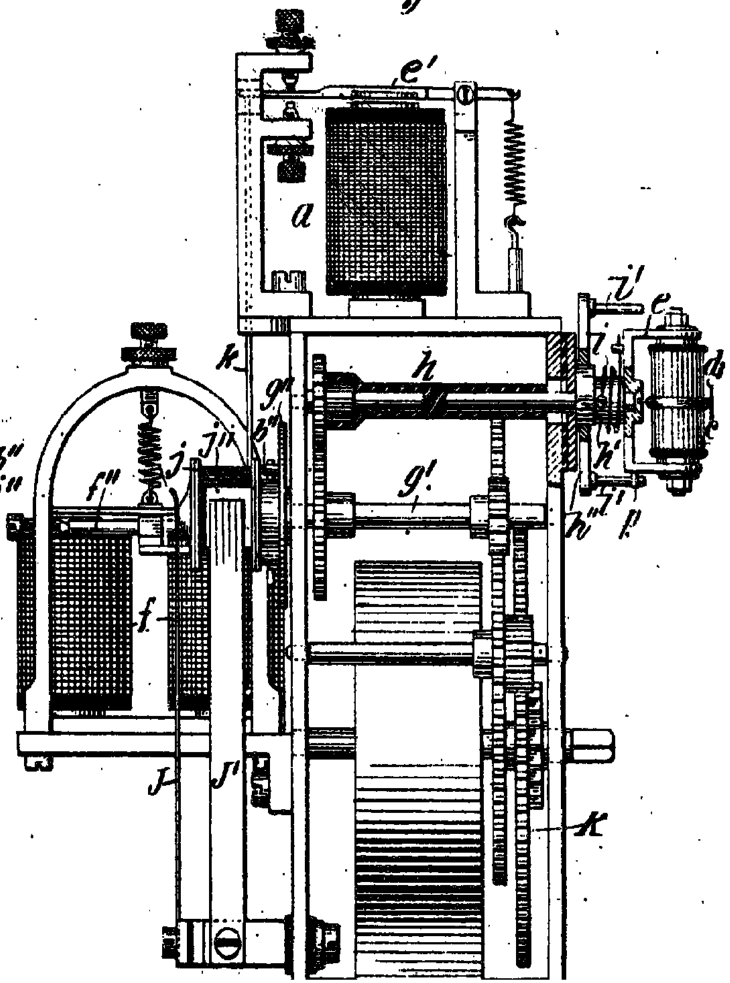


Fig. 6



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A.D. 1898. Dec. 13. No. 26,371.
TESLA'S COMPLETE SPECIFICATION.

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SHEET 5.

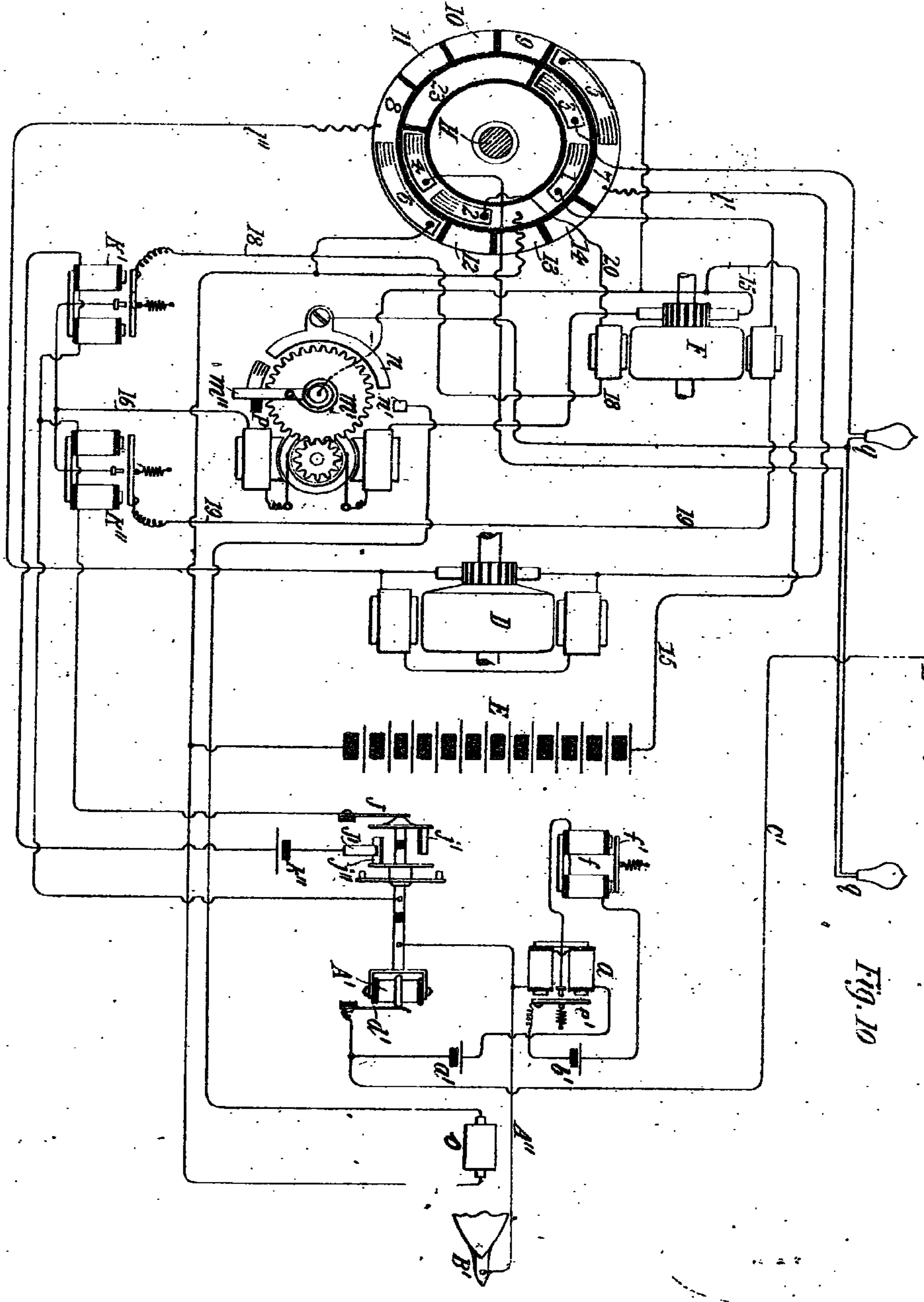

Fig. 10

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Nº 11,293 A.D. 1901

Date of Application, 1st June, 1901—Accepted, 2nd Nov., 1901

COMPLETE SPECIFICATION.

Communicated from abroad by Nikola Tesla of 46 East Houston Street New York United States of America Electrician.

"Improvements relating to the Utilization of Electromagnetic, Light, or other like Radiations Effects or Disturbances transmitted through the Natural Media and to Apparatus therefor."

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The subject of the present invention is an improvement in the art of effecting or controlling the operation of receiving apparatus by means of effects transmitted from a distance through the natural media, and it consists in a novel method of and apparatus for collecting or receiving such effects, and utilizing them for various purposes.

The invention is particularly useful in systems of signalling in which distant receiving devices are operated by means of electrical disturbances produced by proper transmitters and conveyed to such receiving devices through the natural media, but it involves, among other things, the employment of apparatus of novel character, which may be used for other purposes, such, for example, as the investigation or utilization of terrestrial solar, or other disturbances, produced by natural causes.

Several ways or methods of developing and transmitting electrical disturbances through the natural media and utilizing the same to operate distant receivers are now known, and have been applied with more or less success for accomplishing a variety of useful results.

One of these ways consists in producing, by a suitable apparatus, rays or radiations, that is, disturbances which are propagated in straight lines through space, directing them upon a receiving or recording apparatus at a distance, and thereby bringing the latter into action. This method is the oldest and best known, and has been brought particularly into prominence in recent years through the investigations of Heinrich Hertz.

Another method consists in passing a current through a circuit, preferably one enclosing a very large area, inducing thereby in a similar circuit situated at a distance, another current, and producing by the latter in any convenient way, the operation of a receiving device.

Still another way, which has also been known for many years is to pass, in any suitable manner, a current through a portion of the ground, as by connecting to two points of the same, preferably at a considerable distance from each other, the two terminals of the generator, and to energize, by a part of the current diffused through the earth, a distant circuit which is similarly arranged and grounded at two points widely apart, and which is made to act upon a sensitive receiver.

These various methods have their limitations, one especially which is common to all being that the receiving circuit or instrument must be maintained in a definite position with respect to the transmitting apparatus, a requirement which often imposes great disadvantages upon the use of the apparatus. In the course

[*Price 8d.*]

of extended investigations of the phenomena connected with this general subject, I have discovered other methods of accomplishing results of this nature which may be briefly described as follows:

In one system the potential of a point or region of the earth is varied by imparting to it intermittent or alternating electrifications through one of the terminals of a suitable source of electrical disturbances, which, to heighten the effect, has its other terminal connected to an insulated body, preferably of large surface and at an elevation. The electrifications communicated to the earth spread in all directions through the same, reaching a distant circuit which, generally, has its terminals arranged and connected similarly to those of the transmitting source, and operates upon a highly sensitive receiver.

Another method is based upon the fact that the atmospheric air, which behaves as an excellent insulator to currents generated by ordinary apparatus, becomes a conductor under the influence of currents or impulses of enormously high electromotive force which I have devised means for generating. By such means air strata which are easily accessible, are rendered available for the production of many desired effects, even at great distances.

Obviously whatever method be employed, it is desirable that the disturbances produced by the transmitting apparatus should be as powerful as possible. Furthermore, since in most cases the amount of energy conveyed to the distant circuit is but a minute fraction of the total energy emanating from the source, it is necessary for the attainment of the best results that, whatever the character of the receiver and the nature of the disturbances, as much as possible of the energy conveyed should be made available for the operation of the receiver, and I have heretofore employed, among other means, a receiving circuit of high self induction and very small resistance, and of a period such as to vibrate in synchronism with the disturbances whereby a number of separate impulses from the source were made to co-operate, thus magnifying the effect exerted upon the receiving device. By these means decided advantages have been secured in many instances, by very often the plan is either not applicable at all, or, if so, the gain is very slight.

Evidently, when the source is one producing a continuous pressure or delivering impulses of long duration, it is impracticable to magnify the effects in this manner, and, when, on the other hand, it is one furnishing short impulses of extreme rapidity of succession, the advantage obtained in this way is insignificant owing to the radiation and the unavoidable frictional waste in the receiving circuit. These losses reduce greatly both the intensity and the number of the co-operating impulses, and, since the initial intensity of each of these is necessarily limited, only an insignificant amount of energy is thus made available for a single operation of the receiver.

As this amount is consequently dependent on the energy conveyed to the receiver by one single impulse, it is evidently necessary to employ either a very large and costly, and, therefore, objectionable transmitter, or else to resort to the equally objectionable use of a receiving device too delicate and too easily deranged. Furthermore, the energy obtained through the co-operation of the impulses is in the form of extremely rapid vibrations and, because of this, unsuitable for the operation of ordinary receivers, the more so as this form of energy imposes narrow restrictions in regard to the mode and time of its application to such devices.

To overcome these and other limitations and disadvantages which have heretofore existed in systems of this character, particularly when used for the transmission of signals or intelligence, the methods and apparatus herein described have been devised for the purpose of intensifying the effects of the transmitted disturbances in order that they might be more readily detected and more efficiently utilized.

The method generally stated may be carried out by the storage of energy either from the original source of the disturbances, or from an independent source, and by the utilization of such stored energy to operate a receiving device. In one case the method is practised by producing arbitrarily varied or intermittent disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving station, utilizing the energy derived from the same at the receiving station to charge a condenser, and using the accumulated potential energy so obtained to operate a receiving device. In another case the stored energy from an independent source is used under the control of the effects or disturbances transmitted through the natural media for operating the receiving device, while a third plan, based upon the property which certain radiations, such as those of ultra-violet light, cathodic or Roentgen rays and the like possess of charging and discharging electric conductors, consists in charging one of the armatures of a condenser by such rays or radiations, and the other by an independent means, and discharging the condenser through a suitable receiver.

The general principles underlying the invention and the construction and mode of operation of the devices which are or which may be used in carrying out the invention, will be understood by reference to the accompanying drawing, in which

Figure 1 is a diagrammatic illustration of the apparatus employed when the energy from the transmitting source is to be stored.

Figure 2 is a diagrammatic illustration of the apparatus employed when the stored energy is obtained from an independent source and merely controlled by the effects transmitted.

Figure 3 is a diagram of a modified arrangement of apparatus for the same purpose, and

Figure 4 is a similar illustration of an apparatus for simultaneously charging a condenser by means of rays or radiations and an independent source of electrical energy, and discharging it through a receiver.

Referring now to Figure 1: At any two points in the transmitting medium between which there exists or may be obtained in any manner, through the action of the disturbances or effects to be utilized or investigated, a difference of electrical potential of any magnitude, I arrange two plates or electrodes 1 2 so that they may be oppositely charged through the agency of such effects or disturbances, and I connect these electrodes to the terminals of a highly insulated condenser 3, generally of considerable capacity. To the condenser terminals there is also connected the receiver 4, in series with a device of suitable construction which performs the function of periodically discharging the condenser through the receiver at and during such intervals of time as may be best suitable for the purpose contemplated. This device may consist merely of two stationary electrodes separated by a feeble dielectric layer of minute thickness, or it may comprise terminials, one or more of which are movable, and actuated by any suitable force, so as to be brought into and out of contact with each other in any convenient manner.

The special device shown for this purpose consists of a cylinder 5, made partly of conducting and partly of insulating material 6 and 7, respectively, which is rotated at the desired rate of speed by any suitable means. The conducting part 6 is in good electrical connection with the shaft 8, and is provided with tapering segments 9, upon which slides a brush 10 supported on a conducting rod 11 capable of longitudinal adjustment in a metallic support 12. Another brush 13 is arranged to bear upon the shaft 8, and it will be seen that wherever one of the segments 9 comes in contact with the brush 10 the circuit, including the receiver 4, is completed and the condenser discharged through the same. By an adjustment of the speed of rotation of the cylinder 5 and a displacement of the brush 10 along the cylinder, the circuit may be made to open and close in as rapid succession, and to remain open or closed during such intervals of time, as may be desired.

It will be readily seen that if the disturbances, of whatever nature they may be, cause definite amounts of electricity, of the same sign, to be conveyed to each of the plates or electrodes 1 and 2, *ie* definite amounts of positive electricity to one & of negative to the other either continuously or at intervals of time which are sufficiently long, the condenser will be charged to a certain potential, and, an adequate amount of energy being thus stored during the time determined by the discharging device, the receiver will be periodically operated by the electrical energy so accumulated.

But very often the character of the impulses and the conditions of their use are such that, without further provision, not enough potential energy would be accumulated in the condenser to operate the receiving device. This is the case when, for example, each of the plates or terminals 1 2 receives quantities of electricity of rapidly changing sign, or even when each receives quantities of electricity of the same sign, but only during periods which are short as compared with the intervals separating them. In such instances, the use of a special device is resorted to, which device is inserted in circuit between the plates 1 2 and the condenser 3, for the purpose of conveying to each of the terminals of the latter electrical charges of the proper quality and order of succession to enable the required amount of potential energy to be stored in the condenser.

One form of such device, which will serve for purposes of illustration of this feature of the invention, consists of a cylinder 14 of insulating material which is moved at a uniform rate of speed by clock-work or other suitable motive power, and is provided with two metal rings 15 16, upon which bear brushes 17 and 18, respectively, and which are connected in the manner shown to the two terminal plates 1 and 2. From the rings 15 16 extend narrow metallic segments 19 and 20, which, by the rotation of the cylinder 14 are brought alternately into contact with double brushes 21 and 22, carried by and in contact with conducting holders 23 and 24, which are adjustable longitudinally in the metallic supports 25 and 26 as shown. The latter are connected to the terminals 27 and 28 of the condenser 3, and it should be understood that they are capable of angular displacement as ordinary brush supports. The object of using two brushes in each of the holders is to vary at will the duration of the electric contact of the plates 1 and 2 with the terminals of the condensers.

The plates 1 and 2, through which the electrifications are conveyed to the brushes 17 and 18, may be at a considerable distance from each other, and both in the ground or both in the air, or one in the ground and the other in the air, preferably at some height, or they may be connected to conductors extending to some distance, or to the terminals of any kind of apparatus supplying electrical energy which is obtained from the energy of the impulses or disturbances transmitted from a distance through the natural media.

In illustration of the operation of the devices described, let it be assumed that alternating electrical impulses from a distant generator, are transmitted through the earth, and that it is desired to utilize these impulses in accordance with the present invention. This may be the case, for example, when such a generator is used for purposes of signalling in one of the ways above stated, as by having its terminals connected to two points of the earth distant from each other. In this case the plates 1 2 are first connected to two properly selected points of the earth; the speed of rotation of the cylinder 14 is varied until it is made to turn in synchronism with the alternate impulses of the generator, and finally, the position of the brushes 21 and 22 is adjusted so that they are in contact with the segments 19 and 20 during the periods when the impulses are at or near the maximum of their intensity.

Only ordinary electrical skill and knowledge are required to make these adjustments, and a number of devices for effecting synchronous movement being well known, a detailed description of such devices is not considered necessary. The above requirements being fulfilled, electrical charges of the same sign will be conveyed to each of the condenser terminals as the cylinder 14 is rotated, and with each fresh impulse the condenser will be charged to a higher potential. The speed of rotation of the cylinder 5 being adjustable at will, the energy of any number of separate impulses may thus be accumulated in potential form and discharged through the receiver 4 upon the brush 10 coming in contact with one of the segments 9. It will be of course understood that the capacity of the condenser should be such as to allow the storing of a much greater amount of energy than is required for the ordinary operation of the receiver. Since by this method a relatively great amount of energy and in a suitable form may be made available for the operation of a receiver, the latter need not be very sensitive, but of course, when the impulses are very feeble, as when coming from a great distance, or when it is desired to operate a receiver very rapidly, then any of the well known devices capable of responding to very feeble influence may be used in this connection.

If instead of alternating impulses short impulses of the same direction are conveyed to the plates 1 and 2, the apparatus described may still readily be used, and for this purpose it is merely necessary to shift the brushes 21 and 22 while maintaining the same condition with regard to synchronism as before, so that the succeeding impulses will be permitted to pass into the condenser, but prevented from returning to the ground or transmitting medium during the intervals between them, owing to the interruption during such intervals of the connections leading from the condenser terminals to the plates.

Another way of using the apparatus with impulses of the same direction is to take off one pair of brushes, as 21, disconnect the plate 1 from the brush 17 and join it directly to the terminal 27 of the condenser, and to connect brush 17 with brush 18. Operated in this manner, and assuming the speed of rotation of cylinder 14 to be the same, the apparatus will now be adapted for a number of impulses per unit of time twice as great as in the preceding case. In all cases it is evidently important to adjust the duration of contact of segments 19 and 20 with brushes 21 and 22 in the manner indicated.

When the method and apparatus described are used for the purpose of transmitting signals or intelligence, the transmitter, it will be understood, is operated in such a way as to produce disturbances or effects which are varied or intermitted in some arbitrary manner, for example, to produce longer and shorter successions of impulses corresponding to the dashes and dots of a telegraph code, and the receiving device will respond to, and indicate, these variations or intermittances, since the storage device will be charged and discharged a number of times corresponding to the duration of the successions of impulses received.

In the form of apparatus for utilizing the stored energy of an independent source, and which is illustrated in Figures 2 and 3, a charging circuit is connected to the terminals 27 and 28 of the condenser 3, and includes a battery 30, a sensitive device 31, and a resistance 32, all connected in series, as shown. The battery should be of very constant electromotive force and of an intensity carefully determined to secure the best results. The resistance 32, which may be a frictional or an inductive one, is not absolutely necessary, but it is of advantage to use it in order to facilitate adjustment, and for this purpose it may be made variable in any convenient manner.

If the disturbances which are to be utilized or investigated are rays identical with or resembling those of ordinary light, the sensitive device 31 may be a selenium cell properly prepared so as to be highly susceptible to the influence of the rays, the action of which should be intensified by the use of a reflector 33. It is well known that when cells of this kind are exposed to such rays of greatly varying intensity, they undergo corresponding modifications of their electrical resistance, but in the ways they have heretofore been used they have been of very limited utility.

In addition to the circuit including the sensitive device or cell, 31, another circuit is provided which is likewise connected to the terminals 27 and 28 of the condenser. This circuit is the same as that described in connection with

Figure 1 and contains a receiver 4 and a device 5 for periodically discharging the condenser through the receiver.

It will be noted that, as shown in Figure 2, the receiving circuit is in permanent connection with the battery and condenser terminal 27, but it is sometimes desirable to entirely insulate the receiving circuit at all times, except at the moments when the device 5 operates to discharge the condenser, thus preventing any disturbing influences which might otherwise be caused in this circuit by the battery or the condenser during the period when the receiver should not be acted upon. In such a case two devices as 5 may be used, one in each connection from the condenser to the receiving circuit, or else one single device of this kind, but of suitably modified construction, so that it will make and break simultaneously and at proper intervals, both connections.

From the foregoing the operation of the apparatus will be understood. Normally, that is, when not influenced by the rays, or very slightly so, the cell 31, being of comparatively high resistance, permits only a relatively feeble current to pass from the battery into the condenser, and hence the latter is charged at too slow a rate to accumulate, during the time interval between two succeeding operations of the device 5, sufficient energy to operate the receiver. This condition is readily secured by a proper selection and adjustment of the various devices described, so that the receiver will remain unresponsive to the feeble discharges of the condenser which may take place when the cell 31 is acted upon but slightly, or not at all, by the rays or disturbances. But if now new rays are permitted to fall upon the cell, or if the intensity of those already acting upon it be increased by any cause, then its resistance will be diminished and the condenser will be charged by the battery at a more rapid rate, enabling sufficient potential energy to be stored in the condenser during the period of inaction of the device 5, to operate the receiver or to bring about any desired change in the receiving circuit when the device 5 acts. If the rays acting upon the cell or sensitive device 31 are varied or intermitted in any arbitrary manner, as when transmitting intelligence in the usual way from a distant station by means of short and long signals, the apparatus may readily be made to record, or to enable an operator to read the message, since the receiver, supposing it to be an ordinary electro-magnetic relay, for example, will be operated by each signal from the sending station a certain number of times having some relation to the duration of each signal. It will be readily seen, however, that if the rays are varied in any other way, as by impressing upon them changes in intensity, the succeeding condenser discharges will undergo corresponding changes in intensity which may be indicated or recorded by a suitable receiver, and distinguished irrespective of duration.

The electrical connections of the various devices illustrated may be made in various ways. For instance, the sensitive device, instead of being in series with, as shown, may be a shunt to the condenser, and in this case the condenser will store less energy when the sensitive device is energized by the rays and its resistance thereby diminished. The adjustment of the various instruments will then be such that the receiver will be operated only when the rays are diminished in intensity, or interrupted and entirely prevented from falling upon the sensitive cell.

The sensitive device may also be placed in shunt to the resistance 32, as well as to the condenser, or the several instruments may be connected in the manner of a Wheatstone bridge, as hereinafter described, but in each case the sensitive device operates to control the energy stored and utilized in some suitable way for actuating the receiver. The condenser may be replaced by other means of storage without departure from the invention.

In Figure 3 I have shown a more complete arrangement of the apparatus, particularly adapted for the investigation or utilization of very feeble impulses or disturbances, such as may be used in conveying signals or producing other desired effects at great distances. In this case the energy stored in the condenser 3 is passed through the primary 34 of a transformer, the secondary 35 of which is in a circuit containing the receiver 4. In order to render the apparatus still more suitable for use in detecting feeble impulses, in addition to the sensitive device 31 which is acted upon by the transmitted impulses, another such device 36 is included in the secondary circuit of the transformer.

The plan of connections is, in the main, that of a Wheatstone bridge, the four branches of which are formed of the sensitive device 31 and resistances 37, 38 and 39, all of which should be preferably inductive and adjustable in a continuous manner. The condenser is connected to two opposite points of the bridge, while a battery 30, in series with a continuously adjustable non-inductive resistance 32, is connected to the other pair of opposite points as usual. The four resistances 31, 37, 38 and 39 are so proportioned that under normal conditions, or when the device 31 is not influenced at all, or only slightly by the disturbances, there will be no difference of potential or, in any case the minimum of the same, at the terminals 27 and 28 of the condenser.

It is assumed in the present instance that the disturbances are such as will produce a difference of electrical potential, however small, between two points in the earth or air, and, in order to apply this potential difference effectively the terminals of the sensitive device are as in Figure 1, two plates, 1 and 2, located at a suitable distance apart. Any form of sensitive device may be employed, that shown being one of familiar construction and consisting of an insulating tube having its ends closed by two conducting plugs with extensions upon which bear brushes 40, through which currents are conveyed to the device. The tubular space between the plugs is partially filled with a conducting sensitive powder. This tube is to be rotated by suitable clock work or otherwise at a uniform rate of speed, under which conditions it behaves towards disturbances of the kind now under consideration in a manner similar to that of a stationary cell of selenium towards rays of light. Its electrical resistance is diminished when it is acted upon by the disturbances and is automatically restored upon cessation of their influence.

The primary 34 is usually of few turns and low resistance, and is in circuit with a discharger 5 of the kind hereinbefore described.

The secondary coil 35 is usually of much finer wire and of many more turns. In circuit therewith is the receiver 4, shown as an ordinary relay; a continuously adjustable non-inductive resistance 41, a battery 42, of a properly determined and very constant electro-motive force and the sensitive device 36 of the same construction as that above described.

The electro-motive force of the battery 42 is so graduated by means of the adjustable resistance 41 that the dielectric layers in the sensitive device 36 are strained very nearly to the point of breaking down, and give way upon a slight increase of the electrical pressure on the terminals of the device. It will of course be understood that other means than the resistances 32 and 41 may be employed for securing the proper adjustment of the apparatus.

The various instruments being connected and adjusted in the manner described, the periodical closing of the primary circuit of the transformer by means of the device 5 will have no appreciable effect so long as the sensitive device 31 remains unaffected. But when, owing to the disturbances or impulses propagated through the media from a distant source, an additional electro-motive force, however small, is created between the terminals of the device 31, the dielectric layers give way and allow the current of the battery 30 to pass through, thus causing a difference of potential at the terminals 27, 28 of the condenser 3. A sufficient amount of energy being now stored in this instrument during the time interval between each two succeeding operations of the device 5, each closure of the primary circuit by the latter results in the passage of a sudden current impulse through the coil 34, which induces a corresponding current of relatively high electro-motive force in the secondary coil 35. This breaks down the resistance of the sensitive device 36 and allows the current of battery 42 to pass and to operate the receiver 4, but only for a moment, since by the rotation of the devices 5, 31 and 36, which may all be driven from the same shaft, the original conditions are restored, assuming, of course, that the electro-motive force set up by the disturbances at the terminals of the sensitive device 31 is only momentary, or of a duration not longer than the time of closure of the primary circuit; otherwise the receiver will be actuated a number of times, and so long as the influence of the disturbances upon the device 31 continues.

In order to render the discharged energy of the condenser more effective in causing the operation of the receiver, the resistance of the primary circuit should be very small and the secondary coil 35 should have a number of turns many times greater than that of the primary coil 34. It is preferable to make the inductive resistances 37 and 38 relatively large, as they are in a shunt to the device 31, and might, if made too small, impair its sensitiveness.

In Figure 4, which illustrates the third method or plan above referred to, 43, represents an insulated plate or conducting body which is to be exposed to the action of rays or radiations, and 44 another plate, the two being connected in series with the condenser 3. The terminals 27 and 28 of the latter are also connected to a circuit containing a receiver 4, and a circuit controlling device which, in this case, is composed of two very thin conducting plates 45, 46, placed in close proximity and very mobile, either by reason of extreme flexibility or owing to the character of their support. To improve their action they should be enclosed in a receptacle, from which the air may be exhausted. The receiver 4 is shown as consisting of an electro-magnet and armature, a retractile spring and a ratchet wheel 47, provided with a spring pawl 48, which is pivoted to the armature as shown. The terminal 44 may be connected to one of the poles of a battery or other source of electricity, or it may itself be, or be connected with any conducting body or object of such properties, or so conditioned, that by its means electricity of the required sign will be supplied to the terminal.

A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor supported at some height in the atmosphere, or to a grounded conductor, the former, as is well known furnishing positive, the latter negative electricity.

The apparatus being arranged as shown, it will be found that when the radiations of the sun or of any other source capable of producing the effects described, fall upon the plate 43 an accumulation of energy in the condenser 3 will result. This phenomenon, I believe, is best explained as follows: The sun, as well as other sources of radiant energy, throws off minute particles of matter positively electrified, which, impinging upon the plate 43, communicate an electrical charge to the same. The opposite terminal of the condenser being connected to the ground, which may be considered as a vast reservoir of negative electricity, a feeble current flows continuously into the condenser and, inasmuch as these supposed particles are of an inconceivably small radius or curvature and consequently charged to a relatively very high potential, this charging of the condenser may continue, as I have found in practice, almost indefinitely, even to the point of rupturing the dielectric. Obviously, whatever circuit controller be employed, it should operate to close the circuit, in which it is included when the potential in the condenser has reached the desired magnitude.

By carefully observing well known rules of design and adjustment of the instruments, the several forms of apparatus above described may be made extremely sensitive and capable of responding to the faintest influences, thus making it possible to utilize impulses or disturbances transmitted from very great distances and too feeble to be detected or utilized in any of the ways heretofore known, and on this account the invention lends itself to many scientific and practical uses of great value.

It is evident that, since one of the chief requirements which the invention herein described is designed to meet is the detection and utilization of feeble transmitted effects, many of the improvements which have been illustrated are also applicable to ordinary telegraphic and telephonic systems involving the use of artificial lines, and such applications I regard as within the scope of my invention and claims.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. The method of utilizing effects or disturbances transmitted from a distance through the natural media, which consists in storing the energy derived from such effects or controlling thereby the storage of energy from an independent source, and using the accumulated energy so obtained to operate a receiving device.

2. The method of utilizing effects or disturbances transmitted from a distance through the natural media, which consists in charging therewith or controlling thereby the charging of a condenser and discharging the accumulated energy through a receiving device.

3. The method of utilizing effects or disturbances transmitted from a distance through the natural media, which consists in charging therewith or effecting thereby the charging of a condenser during any desired time intervals, and discharging the accumulated energy for periods of time predetermined as to succession and duration, through a receiving device.

4. The method herein described of producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving station, establishing thereby a flow of electrical energy in a circuit at such station, charging a condenser with electrical energy from such circuit and discharging the accumulated potential energy so obtained into or through a receiving device at arbitrarily predetermined intervals of time.

5. The method herein described of producing arbitrarily varied or intermitted electrical disturbances or effects, transmitting such disturbances or effects through the natural media to a distant receiving station, establishing thereby a flow of energy in a circuit at such station, selecting and directing the impulses in said circuit so as to render them suitable for charging a condenser, charging a condenser with the impulses so selected or directed and discharging the accumulated potential energy so obtained into or through a receiving device.

6. The method and apparatus described herein and illustrated in Figure 4, by which a condenser is simultaneously charged by rays or radiations and an independent means and discharged through a suitable receiver, either automatically by the accumulated energy or by other means, suitably controlled.

7. The apparatus herein described and illustrated in Figure 1, for receiving and selecting when necessary electrical impulses transmitted through the natural media from a distant source, charging a condenser and discharging the same through a receiver, as set forth.

8. The apparatus herein described and illustrated in Figures 2 and 3, for controlling the charging of a condenser from an independent source, by means of effects or disturbances transmitted from a distance through the natural media, and discharging the same through a condenser.

Dated this 1st day of June 1901.

HASELTINE LAKE & Co.
45 Southampton Buildings, London, W.C., Agents for the Applicant.

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A.D. 1901. JUNE 1. N° 11,293. (1 SHEET)

LAKE'S COMPLETE SPECIFICATION.

Fig. 1

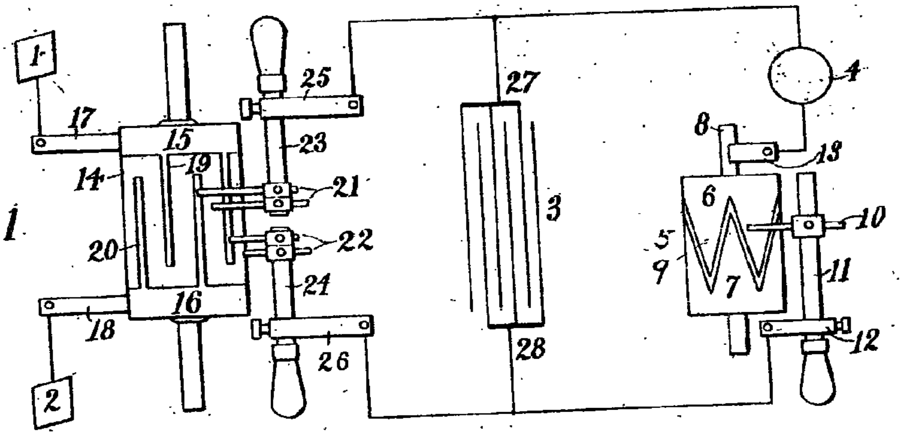


Fig. 2

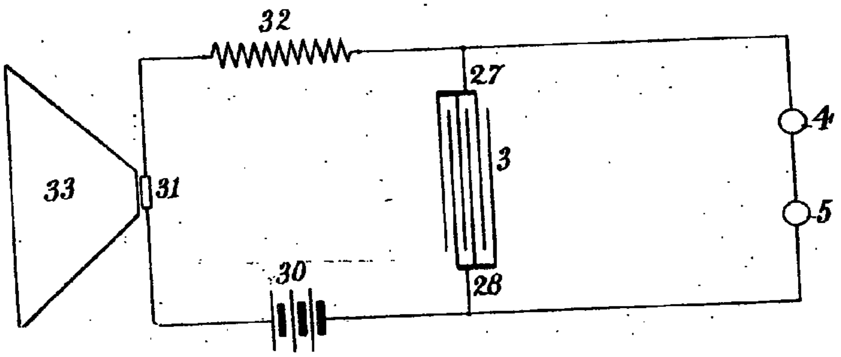


Fig. 3

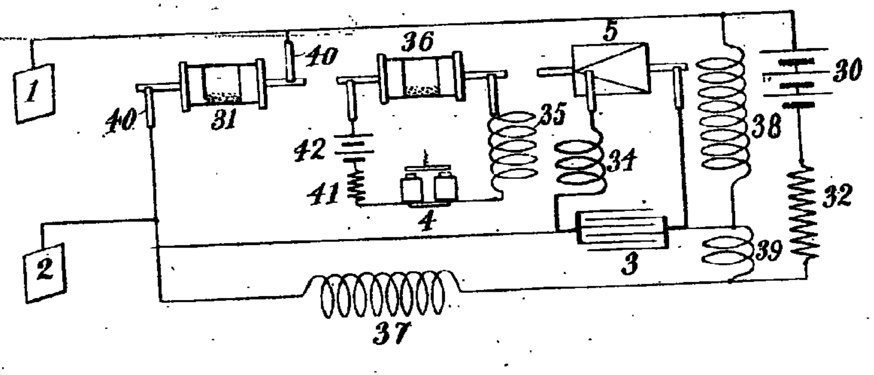
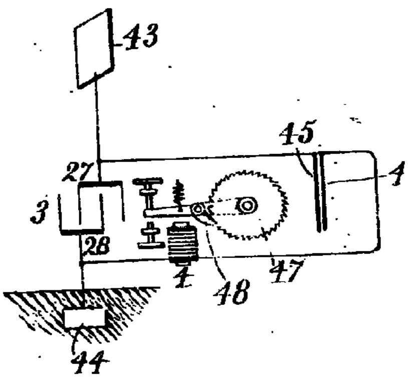


Fig. 4



[This Drawing is a reproduction of the Original on a reduced scale.]

Malby & Sons. Photo-Litho.

N° 13,563 A.D. 1901

Date of Application, 3rd July, 1901—Accepted, 9th Nov., 1901

COMPLETE SPECIFICATION.

Communicated from abroad by Nikola Tesla of 46 East Houston Street City of New York State of New York United States of America, Electrician.

"Improvements in, and relating to, the Transmission of Electrical Energy."

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In many scientific and practical uses of electrical impulses or oscillations, as, for example, in systems of transmitting intelligence to distant points by signals conveyed through artificial channels or through the natural media, it is of great importance to intensify, as much as possible, the current impulses or vibrations, which are produced in the circuits of the transmitting and receiving instruments, particularly of the latter.

It is well known that when electrical impulses are impressed upon a circuit adapted to oscillate freely, the intensity of the oscillations developed in the same is dependent on the magnitude of its physical constants and the relation of the periods of the impressed and of the free oscillations. For the attainment of the best result it is necessary, that the period of the impressed should be the same as that of the free oscillations, under which conditions the intensity of the latter is greatest and chiefly dependent on the inductance and resistance of the circuit, being directly proportionate to the former and inversely to the latter. Evidently then, in order to intensify the impulses or oscillations excited in the circuit, in other words, to produce the greatest rise of current or electrical pressure in the same, it is desirable to make its inductance as large, and its resistance as small as practicable.

Having this end in view, I have devised and used conductors of special and advantageous forms and of relatively very large cross section; but I have found that limitations exist in regard to the increase of the inductance as well as to the diminution of the resistance. This will be understood when it is borne in mind, that the resonant rise of current or pressure in a freely oscillating circuit is proportionate to the frequency of the impulses, and that a large inductance in general involves a slow vibration. On the other hand, an increase of the section of the conductor, with the object of reducing its resistance, is, beyond a certain limit, of little or no value, principally because electrical oscillations, particularly those of high frequency, pass mainly through the superficial conducting layers, and while it is true that this drawback may be overcome in a measure by the employment of thin ribbons, tubes or stranded cables, yet in practice other disadvantages arise, which often more than offset the gain.

It is a well-established fact that, as the temperature of a metallic conductor rises, its electrical resistance increases, and in recognition of this, constructors of commercial electrical apparatus have since long ago resorted to many expedients for preventing the coils and other parts of the same from becoming heated when in use, but merely with a view to economizing energy and reducing the cost of construction and operation of the apparatus.

Now I have discovered, that when a circuit adapted to vibrate freely is main-

[*Price* 8*d*.]

tained at a low temperature, the oscillations excited in the same are, to an extraordinary degree, magnified and prolonged, and I am thus enabled to produce many valuable results, which have heretofore been wholly impracticable.

Briefly stated, then, my invention consists in producing a great increase in the intensity and duration of the oscillations excited in a freely vibrating or resonating circuit, by maintaining the same at a low temperature.

Ordinarily, in commercial apparatus, such provision is made only with the object of preventing wasteful heating and, in any event, its influence upon the intensity of the oscillations is very slight and practically negligible, for as a rule, impulses of arbitrary frequency are impressed upon a circuit, irrespective of its own free vibrations, and a resonant rise is expressly avoided. My invention, it will be understood, does not, primarily, contemplate the saving of energy, but aims at the attainment of a distinctly novel and valuable result; that is, the increase, to the greatest practicable degree, of the intensity and duration of free oscillations. It may be usefully applied in all cases when this special object is sought, but offers exceptional advantages in those instances in which, the freely oscillating discharges of a condenser are utilized.

The best and most convenient manner of carrying out the invention of which I am now aware, is to surround the freely vibrating circuit or conductor, which is to be maintained at a low temperature, with a suitable cooling medium, which may be any kind of freezing mixture or agent, such as liquid air, and in order to derive the fullest benefit from the improvement, the circuit should be primarily constructed so as to have the greatest possible self-induction and the smallest practicable resistance, and other rules of construction, which are now recognized, should be observed. For example, when, in a system of transmission of energy for any purpose through the natural media, the transmitting and receiving conductors are connected to earth and to an insulated terminal respectively, the lengths of these conductors should be one quarter of the wave length of the disturbance propagated through them.

In the accompanying drawing I have shown graphically a disposition of apparatus, which may be used in applying practically my invention.

The drawing illustrates in perspective two devices, either of which may be the transmitter, while the other is the receiver. In each there is a coil of few turns and low resistance, designated in one by A, and in the other by A^1. The former coil, supposed to be forming part of the transmitter, is to be connected with a suitable source of current, while the latter is to be included in circuit with a receiving device.

In inductive relation to said coils in each instrument is a flat spirally wound coil B, or B^1, one terminal of which is shown as connected to a ground plate C, while the other, leading from the center, is adapted to be connected to an insulated terminal.

The coils B, B^1 are placed in insulating receptacles D, which contain the freezing agent and around which the coils A and A^1 are wound.

Coils in the form of a flat spiral, as those described, are eminently suited for the production of free oscillations, but obviously, conductors or circuits of any other form may be used, if desired.

From the foregoing the operation of the apparatus will now be readily understood. Assume first, as the simplest case, that upon the coil A of the transmitter impulses or oscillations of an arbitrary frequency and irrespective of its own free vibrations, are impressed. Corresponding oscillations will then be induced in the circuit B which, being constructed and adjusted as before indicated, so as to vibrate at the same rate, will greatly magnify them, the increase being directly proportionate to the product of the frequency of the oscillations and the inductance of circuit B, and inversely to the resistance of the latter. Other conditions remaining the same, the intensity of the oscillations in the resonating circuit B will be increased in the same proportion as its resistance is reduced. Very often, however, the conditions may be such that the gain sought is not realized directly by diminishing the resistance of the circuit. In such cases the skilled expert who applies my invention, will turn to advantage the reduction of resistance by using a correspondingly longer conductor, thus securing a much greater self-induction and, under all circumstances, he will determine the dimensions of the circuit so as to get the greatest value of the ratio of its inductance to its resistance, which determines the intensity of the free oscillations.

The vibrations of coil B, greatly strengthened, spread to a distance and on reaching through the ground or other conducting medium the tuned receiving conductor B^1, excite corresponding oscillations in the same, which, for similar reasons, are intensified, with the result of inducing correspondingly stronger currents or oscillations in circuit A^1, including the receiving device.

When, as may be the case in the transmission of intelligible signals, the circuit A is periodically closed and opened, the effect upon the receiver is heightened in the manner above described not only because the impulses in the coils B and B^1 are strengthened, but also on account of their persistance through a longer interval of time. The advantages offered by my invention are still more fully realized when the circuit A of the transmitter, instead of having impulses of an arbitrary frequency impressed upon it, is permitted to vibrate itself at its own rate, and more particularly so, if it be energized by the freely oscillating high frequency discharges of a condenser.

In such a case, the cooling of the conductor A, which may be effected in any suitable manner, results in an extraordinary magnification of the oscillation in the resonating circuit B, which I attribute to the increased intensity as well as greater number of the high frequency oscillations obtained in the circuit A. The receiving coil B^1 is energized stronger in proportion and induces currents of greater intensity in the circuit A^1. Evidently, if desired, the latter may be also tuned and kept at a low temperature with the object above set forth in view, and it will be clear, that the greater the number of the freely vibrating circuits which alternately receive and transmit energy from one to another, the greater, relatively, will be the gain secured by applying my invention.

I do not, of course, intend to limit myself to the specific manner and means described of artificial cooling, nor to the particular forms and arrangements of the circuits shown. By taking advantage of the facts above pointed out and of the means described, I have found it possible to secure a rise of electrical pressure in an excited circuit very many times greater than has heretofore been obtainable, and this result makes it practicable, among other things, to greatly extend the distance of transmission of signals and to exclude much more effectively interferences with the same than has been possible heretofore.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. The combination with a circuit adapted to vibrate freely, of means for artificially cooling the same to a low temperature, as herein set forth.

2. In an apparatus for transmitting or receiving electrical impulses or oscillations, a primary and a secondary circuit, one or both adapted to vibrate freely in response to the impressed oscillations, and means for artificially cooling the excited circuit or circuits to a low temperature, as herein set forth.

3. In a system for the transmission of electrical energy, a circuit upon which electrical oscillations are impressed, and which is adapted to vibrate freely, and a receptacle containing an artificial refrigerant in which said circuit is immersed, as herein set forth.

4. The means of increasing the intensity of the electrical impulses or oscillations impressed upon a freely vibrating circuit, consisting of an artificial refrigerant applied to such circuit and adapted to maintain the same at a low temperature.

5. The means of intensifying and prolonging the electrical oscillations pro-

duced in a freely vibrating circuit, consisting of an artificial refrigerant applied to such circuit and adapted to maintain the same at a uniformly low temperature.

6. In a system for the transmission of energy, a series of transmitting and receiving circuits adapted to vibrate freely, and means for artificially maintaining the same at a low temperature, as set forth.

Dated this 3rd day of July 1901.

HASELTINE, LAKE & Co.,
45 Southampton Buildings, London, W.C.,
Agents for the Applicant.

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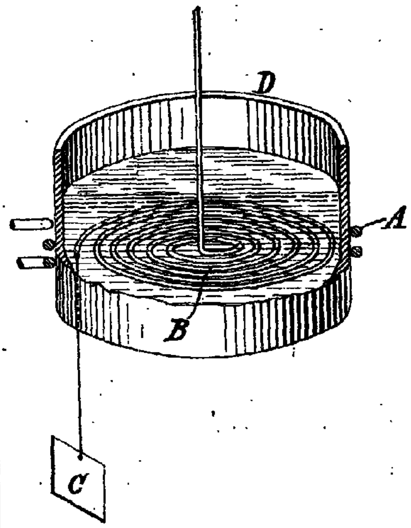
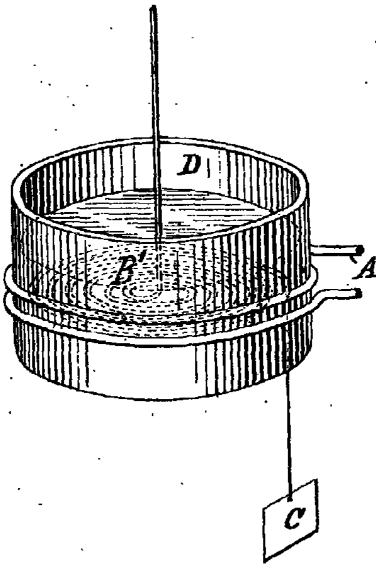
A.D. 1901. July 3. No. 13,563.

LAKE'S Complete Specification.

(1 Sheet)





[This Drawing is a reproduction of the Original on a reduced scale.]

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N° 14,579 A.D. 1901

Date of Application, 17th July, 1901—Accepted, 24th Apr., 1902

COMPLETE SPECIFICATION.

Communicated from abroad by Nikola Tesla, of 46 East Houston Street, Borough of Manhattan, City, County and State of New York, United States of America, Electrician.

"Improvements in and relating to the Transmission of Electrical Energy".

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In certain systems for transmitting intelligible messages, or governing the movements and operations of distant automata, electrical impulses or disturbances, produced by suitable apparatus, are conveyed through the natural media to a receiving circuit, capable of responding to the impulses and thereby effecting the control of other appliances. Generally a special device, highly sensitive, is connected to the receiving circuit which, in order to render it still more susceptible and to reduce the liability of its being affected by extraneous disturbances, is carefully synchronized with the transmitter. By a scientific design of the sending and receiving circuits and other apparatus, and skillful adjustment of the same, these objects may be in a measure attained, but notwithstanding all constructive advantages and experimental resources, this method is in many cases inadequate. Thus, while it is practicable to operate, selectively, under certain favorable conditions, more than one hundred receivers, in most cases it is possible to work successfully but a few, the number rapidly diminishing as, either owing to great distance or other causes, the energy available in the synchronized circuits becomes smaller, and therefore the receivers necessarily more delicate. Evidently a circuit, however excellently constructed and adjusted to respond exclusively to vibrations of one period, is apt to be affected by higher harmonics, and still more so by fundamental tones. When the oscillations are of a very high frequency, the number of the effective harmonics may be large, and the receiver is consequently easily disturbed by extraneous influences, to such an extent that, when very short waves, as those produced by Hertzian spark apparatus, are employed, little benefit in this respect is derived from synchronizing the circuits. It being an imperative requirement in most practical applications of such systems of signalling or intelligence transmission, that the signals or messages should be exclusive or private, it is highly desirable to do away with the above limitations, all the more so, as it is a fact, that the influence of powerful electrical disturbances upon sensitive receivers extends, even on land, to distances of many hundreds of miles and consequently, in accordance with theory, still farther on sea.

To overcome these drawbacks and to enable a great number of transmitting and receiving stations to be operated, selectively and exclusively, and without any danger of the signals or messages being disturbed or intercepted, or interfered with in any way, is the object of my present improvement.

Broadly stated, my invention involves the employment of means for generating two or more kinds or classes of disturbances, waves or impulses of distinctive character, with respect to their effect upon a receiving apparatus, and a distant receiver, which comprises two or more elements, severally responsive to the

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different disturbances or impulses, and which is dependent for operation upon the conjoint or resultant action of two or more such elements.

By employing only two kinds of disturbances or impulses instead of one, as has heretofore been done, to operate a receiver, safety against the disturbing influences of other sources is increased to such an extent, that this number is probably amply sufficient in most cases for rendering the exchange of signals or messages reliable and exclusive, but in exceptional instances a greater number may be used, and a degree of safety against mutual and extraneous interference attained, such as is comparable to that afforded by a combination lock. The liability of a receiver being affected by disturbances emanating from other sources, as well as that of the signals or messages being received by instruments for which they are not intended may, however, be reduced not only by an increased number of the co-operative disturbances or series of impulses, but also by a judicious choice of the same, order and mode in which they are made to act upon the receiver.

Evidently there are a great many ways of generating impulses or disturbances of any wave-length, wave-form, number or order of succession, or of any desired special character, such as will be capable of fulfilling the requirements above stated, and there are also many ways in which such impulses or disturbances may be made to co-operate and to cause the receiver to be actuated and, inasmuch as the skill and practical knowledge in these novel fields can only be acquired by long experience, the degree of safety and perfection attained will necessarily depend on the ability and resource of the expert who applies my invention, but in order to enable the same to be successfully practised by any person possessed only of the more general knowledge and experience in these branches, I shall describe the simplest plan of carrying it out, which is at present known to me.

For a better understanding of the subject, reference is now made to the drawing, in which.

Fig. 1 and Fig. 2 represent diagrammatically the apparatus and circuit connections at the sending and receiving stations, respectively, and

Figs. 3, 4 and 5 modified means which may be employed in the practical application of my invention.

In Fig. 1 S^1 and S^2 are two spirally wound coils or conductors, connected with their inner ends to preferably elevated terminals D^1 and D^2 respectively, and with their outer ends to an earth plate E. These two coils, conductors or systems D^1 S^1 E and D^2 S^2 E have different and suitably chosen periods of vibration and, their lengths should be such that the points of maximum pressure developed therein coincide with the elevated terminals D^1 D^2. By suitably chosen periods of vibration such periods are meant as will secure the greatest safety against interference, both mutual and extraneous. The most satisfactory results in this respect, are obtained when the different periods are related as the reciprocals of the smallest relative prime numbers, but whether this relation be observed or not, the vibrations should be so selected as to give, when passing through or acting upon a common path or circuit, the greatest practicable number of beats in the same. They should furthermore, as regards pitch, not approach too closely those of the order of the Hertzian, because with vibrations of such transcending rates, owing to the rapid radiation of energy into space, resonating systems, as D^1 S^1 E and D^2 S^2 E will not prove efficient intensifiers. The two systems may have electrical oscillations impressed upon them in any desired manner, conveniently by energizing them through primaries P^1 and P^2, placed in proximity to them. Adjustable inductances L^1 and L^2 are preferably included in the primary circuits chiefly for the purpose of regulating the rate of the primary oscillations. In the drawing these primaries P^1 and P^2 surround the coils S^1 S^2, and are joined in series through inductances L^1 L^2, conductor F, condensers C^1 and C^2, brush-holders B^1 and B^2 and a toothed disk D, which is connected to the conductor F and, if desired, also to the groundplate E, as shown. two independent primary circuits being thus formed. The condensers C^1 and C^2 are of such capacity and the inductances L^1 and L^2 are so adjusted that each primary is in close resonance with its secondary system. Care should be taken to obtain in each of the secondary systems D^1 S^1 E and D^2 S^2 E the true or fundamental note, as otherwise the apparatus may not perform satisfactorily. Assuming the capacities of the conductors S^1 and S^2 relatively small, the true notes will result when the product of capacity and inductance in each of the primaries is approximately equal to four times this product in each of the secondaries. The brush-holders B^1 and B^2 are capable, independently of angular and, if necessary, also of lateral adjustment, so that any desired order of succession or any difference of phase may be obtained between the discharges occurring in the two primary circuits. The condensers being energized from a suitable source S, preferably of high potential, and the disk D being rotated, its projections or teeth p p, coming at periodically recurring intervals in very close proximity to or, as the case may be, in contact with conducting rods or brushes n n, cause the condensers to be discharged in rapid succession through their respective circuits. In this manner the two secondary systems, D^1 S^1 E and D^2 S^2 E, are set in vibration and oscillate freely, each at its proper rate for a certain interval of time at every discharge. The two vibrations are impressed upon the ground through the plate E, and spread to a distance, reaching the receiving station, which has two similar circuits or systems e s^1 d^1 and e s^2 d^2, arranged and connected in the same manner and synchronized with the systems at the sending station, so as to respond each exclusively to one of the two vibrations of one kind or class produced by the transmitting apparatus. The same rules of adjustment are observed in the receiving circuits, care being furthermore taken that the synchronizing be effected when all the apparatus is connected to the circuits and placed in position, as any change may more or less modify the vibration. Each of the receiving coils s^1 and s^2 is shunted by a local circuit containing, respectively, sensitive devices a^1 a^2, batteries b^1 b^2, adjustable resistances r^1 r^2, and sensitive relays R^1 R^2, all joined in series as shown. The precise connections and arrangements of the various instruments are largely immaterial, and may be varied in a great many ways. The sensitive devices a^1 and a^2 may be any of the well-known devices, as for example, two conducting terminals separated by a minute air-gap or thin film of dielectric, which is strained or weakened by a battery or other means to the point of breaking down, and gives way to the slightest disturbing influence. Its return to the normal sensitive state may be secured by momentarily interrupting the battery circuit after each operation, or otherwise. The relays R^1 R^2 have armatures l^1 l^2, which are connected by a wire w, and when attracted, establish electrical contacts at c^1 and c^2, thus closing a circuit containing a battery b^3, an adjustable resistance r^3 and a relay R^3. From the above description it will be readily seen that the relay R^3 will be operated only when both contacts c^1 and c^2 are closed.

The apparatus at the sending station may be controlled in any suitable manner, as, for instance, by momentarily closing the circuit of the source S, two different electrical vibrations being emitted simultaneously or in rapid succession, as may be desired, at each closure of the circuit. The two receiving circuits at the distant station, each responding to the vibration produced by one of the elements of the transmitter, affect the sensitive devices a^1 and a^2 and cause the relays R^1 and R^2 to be operated and contacts c^1 and c^2 closed, thus actuating the receiver or relay R^3, which in turn establishes a contact c^3 and brings into action a device a^3 by means of a battery b^4 included in a local circuit, as shown. But evidently, if through any extraneous disturbance only one of the circuits at the receiving station is affected, the relay R^3 will fail to respond. In this way communication may be carried on with much increased safety against interference, and privacy of messages may be secured. The receiving station shown in Fig. 2 is supposed to be one requiring no return message, but if the use of the system is such that this is necessary, then the two stations may be equipped similarly, and any well-known means, which it is not thought necessary to illustrate here, may be resorted to for enabling the apparatus at each station to be used in turn as transmitter and receiver.

The terminals D^1 D^2 of the transmitting, and d^1 d^2 of the receiving apparatus are shown insulated from each other, but this, while advantageous, is not absolutely necessary, and each pair may be connected together, or else a single terminal, as D^1 or d^1, may be used at either of the stations, instead of two, as illustrated.

In like manner the operation of a receiver, as R^3, may be made dependent, instead of upon two, upon more than two such transmitting circuits or systems, and in this way any desired degree of exclusiveness or privacy and safety against extraneous disturbances may be attained. The apparatus, as illustrated in Fig. 1 and Fig. 2 permits, however, specific results to be secured by the adjustment of the order of succession or phase difference between the discharges of the primary circuits P^1 and P^2. To illustrate, the action of the relays R^1 R^2 may be regulated either by adjusting the weights of the levers l^1 l^2, or the strength of the batteries b^1 b^2, or the resistances r^1 r^2, or otherwise, so that, when a certain order of succession or difference of phase between the discharges of the primary circuits P^1 and P^2 exists at the sending station, the levers l^1 and l^2 will close the contacts c^1 c^2 at the same instant, and thus operate the relay R^3, but will fail to produce this result when the order of succession or difference of phase is another one. By these or similar means additional safety against disturbances from other sources may be obtained and, on the other hand, the possibility afforded of effecting the operation of signalling by varying the order of succession of the discharges in the two circuits. Instead of closing and opening the circuit of the source S, as before indicated, for the purpose of sending distinct signals, it may be convenient to merely alter the period of either of the transmitting circuits arbitrarily in any of the well-known ways, as by varying the inductance of the primaries. It should be stated, furthermore, in regard to the apparatus illustrated in Fig. 2, that special and useful results are obtainable by connecting contacts c^1 and c^2 in multiple arc instead of in series, as shown, in which case the relay R^3 will be necessarily either provided with two windings each controlled by one of the contacts, or otherwise constructed or adjusted so that it will not operate unless both of the contacts are closed.

Obviously there is no necessity for using transmitters with two or more distinct elements or circuits, as S^1 and S^2, since a succession of waves or impulses of different characteristics may be produced by an instrument having but one such circuit. A few of the many ways which will readily suggest themselves to the expert who applies my invention, are illustrated in Figs. 3, 4 and 5. In Fig. 3 a transmitting system e s^3 d^3 is partly shunted by a rotating wheel or disk D^3, which may be similar to that illustrated in Fig. 1, and which cuts out periodically a portion of the coil or conductor s^3, or, if desired, bridges it by an adjustable condenser C^3, thus altering the vibration of the system e s^3 d^3 at suitable intervals and causing two distinct kinds or classes of impulses to be emitted in rapid succession by the sender. In Fig. 4 a similar result is produced in the system e s^4 d^4 by periodically short-circuiting a secondary p^4, through an induction coil L^3 and a rotating disk D^4 with insulating and conducting segments, or otherwise. Again, in Fig. 5 three distinct vibrations are caused to be emitted by a system e s^5 d^5, the result being produced by inserting periodically a suitable number of turns of an induction coil L^4 in series with the oscillating system by means of a tating disk D^5 with two projections p^5 p^5, and three rods or brushes n^5, placed at an angle of one hundred and twenty degrees relative to each other. The three transmitting systems or circuits last described may be energized as those in Fig. 1 or in any other convenient way. Corresponding to each of these cases, the receiving station may be provided with two or three circuits, in an analogous manner to that illustrated in Fig. 2, it being understood, of course, that the different vibrations or disturbances emitted by the sender follow in such rapid succession upon each other that they are practically simultaneous, as far as the operation of the relays, such as R^1 and R^2 is concerned. Evidently, however, it is not necessary to employ two or more receiving circuits as s^1 and s^2, but single circuits may be used also at the receiving stations, constructed and arranged like the transmitting circuits or systems illustrated in Figs. 3, 4 and 5, in which case the corresponding disks, as D^3, D^4, D^5 at the sending will be driven in synchronism with those at the receiving stations, though this will not always be necessary.

The disks or other circuit controlling devices, operating synchronously at both the stations, may be constructed so as to enable the transmission of the impulses in any desired fixed or varying order of succession; and it is to be remarked that they will afford additional safety against interference in this instance, while they might prove ineffective in ordinary systems in which but one kind of disturbance is employed to operate a receiver.

To illustrate other useful features, reference may be again made to Figs. 1 and 2. I have found no difficulty in modifying the transmitting apparatus shown in Fig. 1 in such a way, that it will emit, instead of two, four vibrations of different periods. I accomplish this result by properly adjusting the inductances and capacities and the mutual induction co-efficients of the two primary and secondary systems. During the time interval when a primary circuit, as P^1, is closed by the make and break device B^1 D B^2, the secondary circuit S^1 in inductive relation to it may be made to vibrate at a different and considerably higher rate, owing to the diminution of its co-efficient of self-induction through the mutual induction of the circuits, and by proper adjustments of the quantities above named four oscillations of suitable frequency are generated by the transmitter. This being the case, the receiving station may be provided with two sets of apparatus, as illustrated in Fig. 2, and there will then be four relays or devices as R^1 R^2, which may be co-operatively connected or associated either in the manner shown in Fig. 2 or in any other convenient way, but so, that the desired effect upon a receiver will be produced only when all four receiving circuits are energized, and will not take place under any other circumstances.

When it is desired to modify the apparatus as and for the purpose above stated, the various quantities may be determined as follows: Designating, for the sake of convenience, by letters D^1 and S^1 respectively the terminal capacity and the inductance of the secondary system, its fundamental note, when the primary is open, will be of a suitably selected period $T^1 = \frac{1}{n^1 k} = \frac{2\pi}{10^3} \sqrt{4 D^1 S^1}$ D^1 expressing the capacity of the elevated terminal in microfarads and S^1 the inductance of the secondary coil in Henrys. In conformity with the preceding the influence of the primary circuit should be so regulated that, when it is closed by the make and break device D the vibration in the secondary will be of a smaller and arbitrarily chosen period $T^2 = \frac{1}{n^2 k}$ such that $\frac{T^1}{T^2} = \frac{\frac{1}{n^1 k}}{\frac{1}{n^2 k}} = \frac{n^2}{n^1}$, n^2 and n^1 being, preferably, small relative prime numbers and k a constant.

Designating further, conveniently, the inductance of the primary turn or turns in inductive relation to the secondary by the letter P^1, and the mutual induction co-efficient by M, the inductance of the secondary, when the primary circuit is closed, will be reduced to a value $S^1 \left(1 = \frac{M^2}{P^1 S^1}\right)$ and the period will be approximately $T^2 = \frac{2\pi}{10^3} \sqrt{4 D^1 S^1 \left(\frac{1-M^2}{P^1 S^1}\right)}$ Similarly, if letters C^1 and L^1 denote respectively the capacity in the primary circuit and inductance of the adjustable primary coil, the period of the primary circuit will likewise be $T^2 = \frac{2\pi}{10^3} \sqrt{C^1 \left[L^1 + P^1 \left(1 - \frac{M^2}{P^1 S^1}\right)\right]}$ Either of the two expressions found for T^2 may be used in the determinations of the quantities, but the latter is preferable, and it will be found most suitable in practice to ascertain the constants C^1, P^1, M and S^1 by measurement and calculate the approximate number of turns of coil L^1, which permits of easy and precise adjustment by actual experiment.

The above given values for the two periods of the resonating grounded system as D^1 S^1 E hold good only when the conductors, as S^1, are directly connected to the ground. When, as the case may be, a condenser is interposed in the ground connection, the values will be modified in a way well known to experts.

A difficulty may be experienced in securing the proper attunement of a number of circuits of different periods when, as in the instance last described, they are excited through a common medium or channel. The task will be facilitated by graduating the effects in the circuits, which may be done by the adjustment of the ratio of the inductance to the resistance, or otherwise. As a rule it will be found desirable to equalize the actions of the several circuits as much as possible. In connection with the above it is useful to state, that an advantage may be secured by the employment of a circuit-making and breaking device, similar to that illustrated in Fig. 5, for the purpose of connecting the four receiving circuits intermittently to the ground, instead of permanently, it being understood, of course, that the effect of the various circuits upon the receiver is practically simultaneous. Such a device is valuable also in ordinary systems, as, for instance, when it is desired to receive signals from a number of stations at the same time.

By using a transmitter emitting four different vibrations or classes of impulses distinctive in their effect upon as many elements of a receiver, eleven receiving stations can be operated, that is, six by combining two of the vibrations, with great safety, four by combining three of the vibrations, with a safety enormously increased, and one by combining all the four vibrations with a safety which, for most practical purposes, may be considered absolute. The various receivers will obviously be distributed to suit the importance of the several stations. The degree of safety, as well as the number of stations which may be selectively operated, can be still further increased by producing the impulses at the transmitting stations in any arbitrary order of succession which, if desired, may be continuously varied, and using them, at the various receiving stations, to actuate the receivers, in accordance with a predetermined understanding, code, key or safety combination.

Obviously transmitters and receivers may be provided with a much greater number of distinctive elements which, combined and associated in every possible way, will permit the selective operation of a practically unlimited number of devices through a common natural or artificial channel, and such a degree of individualization of a receiver, that it will be absolutely secure against extraneous interference and may be safely called into action, whenever desired, from among innumerable devices of its kind.

It will be seen from a consideration of the nature and purposes of the invention, that it is applicable not only to the special system described, in which the transmission of the impulses is effected through the natural media, but to other systems for the transmission of telegraphic or telephonic signals or of energy for any purpose, and whatever be the medium through which the impulses are transmitted, that is to say, the broad principle of making the operation of a receiver dependent upon the conjoint or resultant action of two or more electrically different or tuned circuits is applicable not only to the special system of telegraphy described in which the electrical energy is transmitted through the natural media, but also to such systems as involve the use of a cable or wire as the conducting medium. Moreover, it is not necessary that the energy transmitted should be utilized to operate any special form of telegraphic instrument, or in fact any telegraphic instrument at all, as the receiver may be a relay or similar device which controls any other kind of device, such for example as the steering mechanism of a self propelled vessel. Therefore the invention is, broadly considered, one for the transmission and utilization in a special manner of electrical energy in general.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. In a system for the transmission of energy, the combination with a receiver comprising a plurality of elements and dependent for operation upon their conjoint action, of a means for producing a plurality of distinctive kind of disturbances or impulses, severally adapted to actuate the elements of the receiver, as set forth.

2. In a system for the transmission of electrical energy, the combination with a receiver comprising a plurality of elements and dependent for operation upon their conjoint action, of a transmitter having a plurality of elements capable of severally producing distinctive kinds of disturbances or impulses, each kind being adapted to actuate one only of the elements of the receiver, as set forth.

3. In a system for the transmission of electrical energy, the combination with a receiver comprising a plurality of elements and dependent for operation upon the conjoint action of two or more of the same, of a transmitter adapted to produce a plurality of distinctive kinds of disturbances or impulses, each kind being adapted to actuate one only of the elements of the receiver, as set forth.

4. In a system for the transmission of electrical energy, the combination with means for producing two or more distinctive kinds of disturbances or impulses, of receiving circuits, each adapted to respond to the waves or impulses of one kind only, and a receiving device dependent for operation upon the conjoint action of the several receiving circuits, as set forth.

5. In a system for the transmission of electrical impulses and the operation or control of signalling or other apparatus thereby, the combination with a transmitter adapted to produce two or more distinctive kinds or classes of disturbances or impulses, of sensitive receiving circuits, each adapted to respond to the impulses or disturbances of one kind or class only, and a receiving device dependent for operation upon the conjoint action of the sensitive circuits, as set forth.

6. In a system for the transmission of electrical impulses, and the operation or control of signalling, or other apparatus thereby, the combination with a transmitter adapted to produce two or more distinctive kinds or classes of disturbances or impulses, of sensitive circuits at the receiving point or station, each adapted to respond to the impulses or disturbances of one kind or class only, a local circuit arranged to be completed by the conjoint action of the sensitive circuits and a receiving device connected therewith, as set forth.

7. In a system for the transmission of electrical impulses and the operation or control of signalling or other apparatus thereby, the combination with a transmitting apparatus adapted to produce two or more distinctive kinds of disturbances or impulses, of means for varying the relations of the impulses of the several kinds, sensitive circuits each adapted to respond to the impulses or disturbances of one kind only, and a receiving apparatus dependent for operation upon the conjoint action of the sensitive circuits, as set forth.

8. In a system, such as herein described, the combination with a transmitter adapted to produce a plurality of distinctive kinds of electrical disturbances or impulses, of a receiving apparatus comprising a plurality of circuits, a sensitive device and a relay included in each circuit, and adjusted to respond to the impulses or disturbances of one kind only, and a receiving apparatus in a local circuit controlled by the relays and adapted to be completed by the conjoint action of all of said relays, as set forth.

9. In a system of the kind described, the combination with a transmitter adapted to produce two or more series of electrical oscillations or impulses of different frequencies, of a receiving apparatus comprising a plurality of sensitive circuits each tuned to respond to the impulses of one of the series produced by the transmitter, and a signalling device dependent for its operation upon the conjoint action of said circuits, as set forth.

10. The combination with a plurality of transmitter elements, each adapted to produce a series of impulses or disturbances of a distinctive character, and means for controlling and adjusting the same, of a receiver having a plurality of sensitive circuits each adapted to be affected by one of the series of impulses only, and dependent for operation upon the conjoint action of all of said circuits, as set forth.

11. The combination with a transmitter adapted to produce series of electrical impulses or disturbances of distinctive character and in a given order of succession, of a receivng apparatus comprising elements adapted to respond to such impulses in a corresponding order, and dependent for operation upon the conjoint action of said elements, as set forth.

12. In a receiving apparatus, the combination of a plurality of sensitive circuits, each tuned to respond to waves or impulses of a given kind or class, a receiving circuit controlled by the sensitive circuits and a device connected with the receiving circuit adapted to be operated when said circuit is completed by the conjoint action of two or more of the sensitive circuits, as set forth.

13. The method of operating distant receivers which consists in producing and transmitting a plurality of kinds or classes of electrical waves or impulses, actuating by the waves or impulses of each class one of the elements of a receiver, and controlling the operation of the receiver by the conjoint action of two or more of said elements, as set forth.

14. The method of signalling which consists in producing and transmitting a plurality of kinds or classes of electrical waves or impulses, developing by the waves or impulses of each class a current in one of a plurality of receiving circuits and controlling by means of such circuits a local circuit, as set forth.

15. The method of signalling which consists in producing a plurality or series of waves or impulses differing from each other in character or order of succession, exciting by the waves or impulses of each series one of a plurality of receiving circuits and controlling by such circuits a local circuit, as set forth.

16. The method of signalling which consists in producing a plurality or series of waves or impulses, varying the character or order of succession of the several series, exciting by the waves or impulses of each series one of a plurality of receiving circuits and controlling by such circuits a local circuit, as set forth.

Dated this 16th day of July 1901.

HASELTINE, LAKE & Co.,
45 Southampton Buildings, London, W.C.,
Agents for the Applicant.

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A.D. 1901, July 17. N° 14,579.

LAKE'S Complete Specification.

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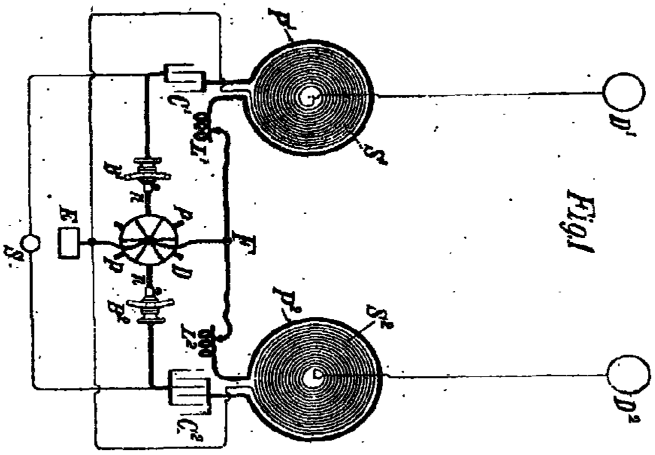

Fig.1

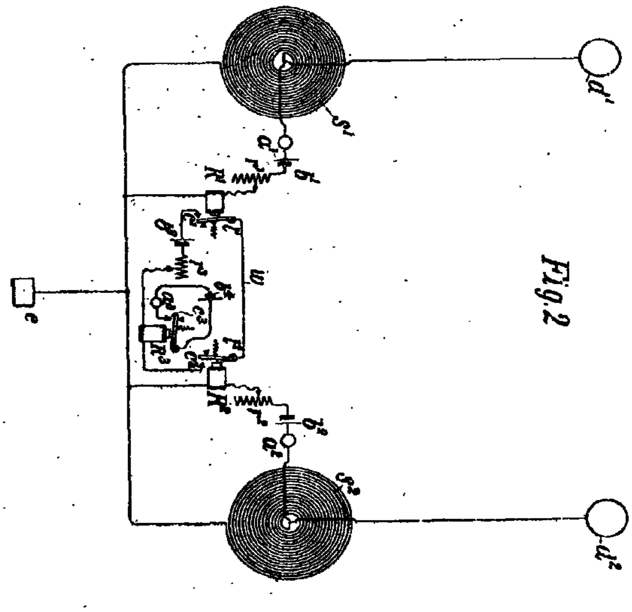

Fig.2

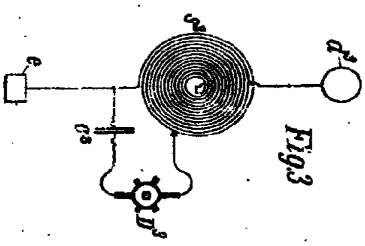

Fig.3

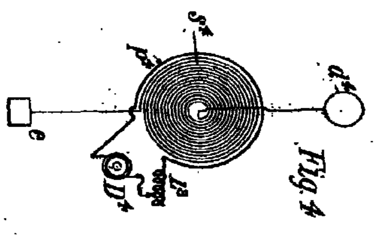

Fig.4

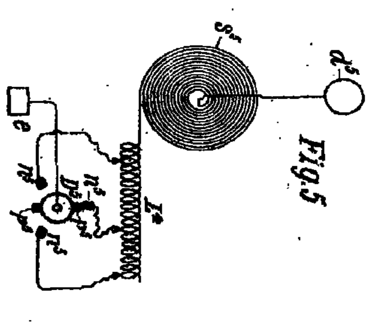

Fig.5

[This Drawing is a reproduction of the Original on a reduced scale]

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N° 8200 A.D. 1905

Date of Application, 17th Apr., 1905—Accepted, 17th Apr., 1906

COMPLETE SPECIFICATION.

Communicated by Nikola Tesla, of New York, United States of America, Electrician.

" Improvements relating to the Transmission of Electrical Energy ".

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 7 & 8 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the transmission of electrical energy.

It has long since been known that electric currents may be propagated through the earth, and this knowledge has been utilised in many ways in the transmission of signals and the operation of a variety of receiving devices, remote from the source of energy, mainly with the object of dispensing with a return conducting wire.

It is also known that electrical disturbances may be transmitted through portions of the earth by grounding only one of the poles of the source, and this fact I have made use of in systems, which I have devised for the purposes of transmitting through the natural media, intelligible signals or power, and which are now familiar. But all experiments and observations heretofore made have tended to confirm the opinion held by the majority of scientific men, that the earth, owing to its immense extent, although possessing conducting properties, does not behave in the manner of a conductor of limited dimensions with respect to the disturbances produced, but on the contrary, much like a vast reservoir, or ocean which, while it may be locally disturbed by a commotion of some kind, remains unresponsive and quiescent in a large part or as a whole.

Still another fact, now of common knowledge is, that when electrical waves or oscillations are impressed upon such a conducting path as a metallic wire, reflection takes place under certain conditions, from the ends of the wire and, in consequence of the interference of the impressed and reflected oscillations, the phenomenon of " stationary waves ", with maxima and minima indefinite, fixed positions, is produced. In any case the existence of these waves indicates, that some of the outgoing waves have reached the boundaries of the conducting path and have been reflected from the same.

Now I have discovered, that notwithstanding its vast dimensions and contrary to all observations heretofore made, the terrestrial globe may, in a large part or as a whole, behave towards disturbances impressed upon it in the same manner as a conductor of limited size, this fact being demonstrated by novel phenomena which I shall hereinafter describe.

In the course of certain investigations which I carried on for the purpose of studying the effects of lightning discharges upon the electrical condition of the earth, I observed that sensitive receiving instruments, arranged so as to be capable of responding to electrical disturbances created by the discharges, at times failed to respond, when they should have done so and, upon inquiring into the causes of this unexpected behaviour, I discovered it to be due to the

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character of the electrical waves, which were produced in the earth by the lightning discharges and which had nodal regions following at definite distances, the shifting source of the disturbances. From data obtained in a large number of observations of the maxima and minima of these waves, I found their length to vary, approximately from twenty-five to seventy kilometres, and these results and certain theoretical deductions led me to the conclusion, that waves of this kind may be propagated in all directions over the globe, and that they may be of still more widely differing lengths, the extreme limits being imposed by the physical dimensions and properties of the earth.

Recognizing in the existence of these waves an unmistakable evidence that the disturbances created had been conducted from their origin to the most remote portions of the globe and had been thence reflected, I conceived the idea of producing such waves in the earth by artificial means, with the object of utilizing them for many useful purposes, for which they are, or might be found applicable.

This problem was rendered extremely difficult, owing to the immense dimensions of the earth and consequently enormous movement of electricity, or rate at which electrical energy had to be delivered in order to approximate, even in a remote degree, movements or rates which were manifestly attained in the displays of electrical forces in nature, and which seemed at first unrealizable by any human agencies. But by gradual and continuous improvements of a generator of electrical oscillations, which I have described in the Specifications of my United States Patents Nos. 645,576 and 649,621, and in the Specification of my British Patent No. 24,421 of 1897, I finally succeeded in reaching electrical movements, or rates of delivery of electrical energy, not only approximating but, as shown in many comparative tests and measurements, actually surpassing those of lightning discharges, and by means of this apparatus I have found it possible to reproduce, whenever desired, phenomena in the earth the same as, or similar to those due to such discharges.

With the knowledge of the phenomena discovered by me and the means at command for accomplishing these results, I am enabled not only to carry out many operations by the use of known instruments, but also to offer a solution for many important problems, involving the operation or control of remote devices which, for want of this knowledge and in the absence of these means, have heretofore been entirely impossible.

For example, by the use of such a generator of stationary waves and receiving apparatus, properly placed and adjusted in any other locality, however remote, it is practicable to transmit intelligible signals; or to control or actuate at will any or all of such apparatus for many other important and valuable purposes, as for indicating, wherever desired, the correct time of an observatory; or for ascertaining the relative position of a body or distance of the same with reference to a given point; or for determining the course of a moving object such as a vessel at sea, the distance traversed by the same or its speed; or for producing many other useful effects at a distance dependent on the intensity, wave-length, direction or velocity of movement, or other feature or property of disturbances of this character.

I shall typically illustrate the manner of applying my discovery by describing one of the specific uses of the same, namely, the transmission of intelligible signals or messages between distant points, and with this object reference is now made to the accompanying drawing, in which:—

Figure 1 represents diagrammatically the generator which produces stationary waves in the earth,

Figure 2 an apparatus, situated in a remote locality, for recording the effects of these waves, and

Figure 3 the usual arrangement of the circuits of my receiving transformer.

In Figure 1 A designates a primary coil forming part of a transformer and consisting generally of a few turns of a stout cable of inappreciable resistance, the ends of which are connected to the terminals of a source of powerful electrical oscillations, diagrammatically represented by G. This source is usually a condenser charged to a high potential, and discharged, in rapid succession through the primary, as in a type of transformer invented by me and now well known, having been described in my patents on apparatus of this kind, of which it will be sufficient to mention my British Patent No. 20,981 of 1896. But when it is desired to produce stationary waves of great lengths, an alternating dynamo of suitable construction may be used to energize the primary A.

C is a spirally wound secondary coil within the primary, having the end nearer the latter connected to the ground E, and the other to an elevated terminal D. The physical constants of coil C, determining its period of vibration, are so chosen and adjusted, that the secondary system E C D is in the closest possible resonance with the oscillations impressed upon it by the primary A. It is moreover, of the greatest importance, in order to still further enhance the rise of pressure and to increase the electrical movement in the secondary system, that its resistance be as small as practicable and its self-induction as large as possible under the conditions imposed. The ground should be made with great care, with the object of reducing its resistance.

Instead of being directly grounded, as indicated, the coil C may be joined, in series or otherwise, to the primary A, in which case the latter will be connected to the plate E. But be it that none, or a part, or all of the primary or exciting turns are included in the coil C, the total length of the conductor from the ground plate E to the elevated terminal should be equal to one quarter of the wave-length of the electrical disturbance in the system E C D, or else equal to that length multiplied by an odd number. This relation being observed, the terminal D will be made to coincide with the points of maximum pressure in the secondary or excited circuit, and the greatest flow of electricity will take place in the same. In order to magnify the electrical movement in the secondary as much as possible, it is essential that its inductive connection with the primary A should not be very intimate, as in ordinary transformers, but loose, so as to permit free oscillation. That is to say, their mutual induction should be small. The spiral form of coil C secures this advantage, while the turns near the primary A are subjected to a strong inductive action and develop a high initial electromotive force.

These adjustments and relations being carefully completed, and other constructive features indicated rigorously observed, the electrical movement produced in the secondary system by the inductive action of the primary A will be enormously magnified, the increase being directly proportionate to the inductance and frequency, and inversely to the resistance of the secondary system. I have found it practicable to produce in this manner an electrical movement thousands of times greater than the initial, that is, the one impressed upon the secondary by the primary A, and I have thus reached activities or rates of flow of electrical energy in the system E C D, measured, by many tens of thousands of horse-power. Such immense movements of electricity give rise to a variety of novel and striking phenomena, among which are those already described. The powerful electrical oscillations in the system E C D, being communicated to the ground, cause corresponding vibrations to be propagated to distant parts of the globe, whence they are reflected and, by interference with the outgoing vibrations, produce stationary waves, the crests and hollows of which lie in parallel circles, relatively to which the ground plate E may be considered to be the pole. Stated otherwise, the terrestrial conductor is thrown into resonance with the oscillations impressed upon it just like a wire. More than this, a number of facts ascertained by me clearly show, that the movement of electricity through it follows certain laws with nearly mathematical rigor. For the present it will be sufficient to state, that the earth behaves like a perfectly smooth or polished conductor of inappreciable resistance, with capacity and self-induction uniformly distributed along the axis of symmetry of wave propagation and transmitting slow electrical oscillations without sensible distortion and attenuation. Besides the above, three requirements seem to be essential to the establishment of the resonating condition.

1. The earth's diameter passing through the pole should be an odd multiple of the quarter wave-length, that is, of the ratio between the velocity of light and four times the frequency of the currents.

2. It is necessary to employ oscillations, in which the rate of radiation of energy into space in the form of Hertzian or electromagnetic waves is very small. To give an idea I would say, that the frequency should be smaller than twenty thousand per second, though shorter waves might be practicable. The lowest frequency would appear to be six per second, in which case there will be but one node, at or near the ground plate, and, paradoxical as it may seem, the effect will increase with the distance and will be greatest in a region diametrically opposite the transmitter. With oscillations still slower the earth, strictly speaking, will not resonate, but simply act as a capacity, and the variation of potential will be more or less uniform over its entire surface.

3. The most essential requirement is, however, that irrespective of frequency, the wave or wave train should continue for a certain interval of time, which I have estimated to be not less than one twelfth—or probably 0.08484—of a second, and which is taken in passing to, and returning from the region diametrically opposite the pole, over the earth's surface, with a mean velocity of about 471,240 kilometers per second.

The presence of the stationary waves may be detected in many ways. For instance, a circuit may be connected directly, or inductively, to the ground and to an elevated terminal, and tuned to respond more effectively to the oscillations. Another way is to connect a tuned circuit to the ground and to two points lying more or less in a meridian passing through the pole E, or generally stated, to any two points of a different potential.

In Fig. 2 I have shown a device for detecting the presence of the waves, such as I have used in a novel method of magnifying feeble effects, which I have described in my United States Patents Nos. 685,953 and 685,955 and my British Patent No. 11,293 of 1901. It consists of a cylinder C^2 of insulating material which is moved at a uniform rate of speed, by clockwork or other suitable motive power, and is provided with two metal rings B B^1, upon which bear brushes a and a^1, connected respectively, to the terminal plates P and P^1. From the rings B and B^1 extend narrow metallic segments S and S^1, which, by the rotation of the cylinder C^2 are brought alternately into contact with double brushes b and b^1, carried by, and in contact with, conducting holders h and h^1, supported in metallic bearings D and D^1, as shown. The latter are connected to the terminals T and T^1 of a condenser C, and it should be understood that they are capable of angular displacement, as ordinary brush supports. The object of using two brushes, as b and b^1, in each of the holders h and h^1, is to vary at will the duration of the electric contact of the plates P and P^1, with the terminals T and T^1, to which is connected a receiving circuit including a receiver R, and a device performing the duty of closing the receiving circuit at predetermined intervals of time and discharging the stored energy through the receiver. In the present case this device consists of a cylinder d made partly of conducting and partly of insulating material e and e^1, respectively, which is rotated at the desired rate of speed by any suitable means. The conducting part e is in good electrical connection with the shaft S, and is provided with tapering segments f f f, upon which slide a brush k supported on a conducting rod l, capable of longitudinal adjustment in a metallic support m. Another brush n is arranged to bear upon the shaft S, and it will be seen that, whenever one of the segments f comes in contact with the brush k, the circuit including the receiver R is completed and the condenser discharged through the same. By an adjustment of the speed of rotation to the cylinder d and a displacement of the brush k along the cylinder the circuit may be made to open and close in as rapid succession, and remain open or closed during such intervals of time, as may be desired.

The plates P and P^1, through which the electrical energy is conveyed to the brushes a and a^1, may be at a considerable distance from each other in the ground, or one in the ground and the other in the air, preferably at some height. If but one plate is connected to the earth and the other maintained at an elevation, the location of the apparatus must be determined with reference to the position of the stationary waves established by the generator, the effect evidently being greatest in a maximum, and zero in a nodal region. On the other hand, if both plates be connected to earth, the points of connection must be selected with reference to the difference of potential, which it is desired to secure, the strongest effect being, of course, obtained when the plates are at a distance equal to half the wave-length.

In illustration of the operation of the system, let it be assumed that alternating electrical impulses from the generator are caused to produce stationary waves in the earth, as above described, and that the receiving apparatus is properly located with reference to the position of the nodal and ventral regions of the waves. The speed of rotation of the cylinder C^2 is varied until it is made to turn in synchronism with the alternate impulses of the generator, and the position of the brushes b and b^1 is adjusted by angular displacement, or otherwise, so that they are in contact with the segments S and S^1 during the periods when the impulses are at, or near, the maximum of their intensity. These requirements being fulfilled, electrical charges of the same sign will be conveyed to each of the terminals of the condenser, and with each fresh impulse it will be charged to a higher potential. The speed of rotation of the cylinder d being adjustable at will, the energy of any number of separate impulses may thus be accumulated in potential form and discharged through the receiver R upon the brush k coming in contact with one of the segments f. It will be understood, that the capacity of the condenser should be such as to allow the storing of a much greater amount of energy than is required for the ordinary operation of the receiver. Since by this amount a relatively great amount of energy, and in suitable form, may be made available for the operation of a receiver, the latter need not be very sensitive. But, when the impulses are very weak, or when it is desired to operate a receiver very rapidly, any of the well-known sensitive devices, capable of responding to very feeble influences, may be used in the manner indicated or in other ways.

Under the conditions described it is evident that during the continuance of the stationary waves, the receiver will be acted upon by current impulses more or less intense, according to its location with reference to the maxima and minima of said waves, but upon interrupting or reducing the flow of the current the stationary waves will disappear or diminish in intensity. Hence a great variety of effects may be produced in a receiver according to the mode, in which the waves are controlled. It is practicable, however, to shift the nodal and ventral regions of the waves at will from the sending station, as by varying the length of the waves under observance of the above requirements. In this manner the regions of maximum and minimum effect may be made to coincide with any receiving station or stations. By impressing upon the earth two or more oscillations of different wave-length a resultant "stationary" wave may be made to travel slowly over the globe, and thus a great variety of useful effects may be produced. Evidently, the course of a vessel may be easily determined without the use of a compass, as by a circuit connected to the earth at two points, for the effect exerted upon the circuit will be greatest when the plates P P^1 are lying on a meridian passing through ground plate E, and will be *nil* when the plates are located at a parallel circle. If the nodal and ventral regions are maintained in fixed positions the speed of a vessel carrying a receiving apparatus may be exactly computed from observations of the maxima and minima regions successively traversed. This will be understood when it is stated, that the projections of all the nodes and loops on the earth's diameter passing through the pole, or axis of symmetry of the wave-movement, are all equal. Hence in any region at the surface the wave length can be ascertained from simple rules of geometry. Conversely, knowing the wave-length, the distance from the source can be readily calculated. In like ways the distance of one point from another, the latitude and longitude, the hour, *etc.*, may be determined from the observation of such stationary waves. If several such generators of stationary waves—preferably of different lengths—were installed in judiciously selected localities, the entire globe could be sub-divided in definite zones of electric activity and such and other important data could be at once obtained by simple calculation or readings from suitably graduated instruments.

The specific plan of producing the stationary waves, herein described, might be departed from. For example, the circuit which impresses the powerful oscillations upon the earth might be connected to the latter at two points.

In collecting the energy of these disturbances in any terrestrial region at a distance from their source, for any purpose, and, more especially, in appreciable amounts, the most economical results will be generally secured by the employment of my synchronized receiving transformer. This invention forming part of my system of transmission of energy through the natural media, has been fully explained in the patents first cited here, but for the better understanding of the present description it is diagrammatically illustrated in Fig. 3. Its most essential part is a circuit E^1 C^1 D^1 which is connected, arranged and adjusted similarly to the transmitting circuit E C D and which is inductively linked with a secondary circuit A^1. The latter, it scarcely need be stated, may be wound with any desired number of turns, such as will be best suited for the operation of the device designated by M. The receiving transformer is closely attuned to the oscillations of the transmitting circuit so that, irrespective of the length of the conductor E^1 C^1 A^1, the points of maximum potential coincide with the elevated terminal D^1, under which conditions the greatest amount of wave energy may be collected and rendered available in the secondary circuit A^1 for useful purposes.

To complete this description, it may be stated that when it is desired to operate, independently, a great many receiving devices, by such stationary waves of different lengths, the principles which I have set forth in my British Patent 14,579 (1901) and in my United States Patents Nos. 723,188 and 725,605 (1903) may be resorted to for rendering the signals or quantities of energy intended for any particular receiver or receivers non-interfering and non-interferable.

In the above, I have briefly outlined my discovery and indicated only a few uses of the same, but it will be readily seen, that it is of transcending importance for the advancement of many arts and industries, new and old, and capable of innumerable valuable applications.

Having now particularly described and ascertained the nature of this invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. The improvement in the art of transmitting electrical energy to a distance which consists in establishing stationary electrical waves in the earth, as set forth.

2. A system in accordance with Claim 1 which consists in establishing in the natural conducting media, stationary electrical waves of predetermined length and operating thereby one or more receiving devices remote from the source of energy and properly located with respect to the position of such waves as herein set forth.

3. The improvement in the art of transmitting electrical energy, which consists in producing in the earth stationary electrical waves of different lengths,

varying their lengths, and causing thereby a resultant wave or effect to travel with the desired velocity over the earth, as above described.

4. The method of producing effects at a distance, which consists in impressing upon the terrestrial globe stationary electrical waves, varying their characteristics and relations, and causing thereby corresponding effects in distant receivers, as above described.

5. The improvement in the art of transmitting and distributing electrical energy, which consists in producing in the terrestrial globe intersecting trains of stationary electrical waves, establishing thereby regions of definite electrical activities, and collecting the energy, as above set forth.

6. The method of producing electrical effects increasing with the distance which consists in impressing upon the earth electrical oscillations of a frequency of about six per second and of such character as to give rise to a stationary electrical wave, as set forth.

7. The method of producing great electrical movements in the terrestrial globe, which consists in rendering it resonant by impressing upon it electrical waves of definite length and duration, as above specified.

8. In the system as hereinbefore described for the transmission of electrical energy, generating apparatus adapted for producing a resonant condition in the terrestrial globe, as above specified.

9. In the system as hereinbefore described for the transmission of electrical energy, a transformer adapted for the production of great electrical movements in the terrestrial globe, as above specified.

10. In the system as hereinbefore described for the transmission of electrical energy, a source of primary electrical oscillations such as a condenser circuit and a secondary circuit inductively linked with the same and adapted for throwing the terrestrial globe into resonance, as above specified.

Dated this 17th day of April, 190 .

HASELTINE, LAKE & Co.,
7 & 8 Southampton Buildings, London, W.C.
Agents for the Applicant.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1906.

A.D. 1905 April 17. N° 8200.
LAKE'S COMPLETE SPECIFICATION.

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Fig. 1.

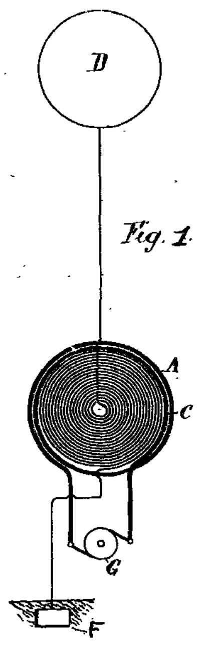


Fig. 2

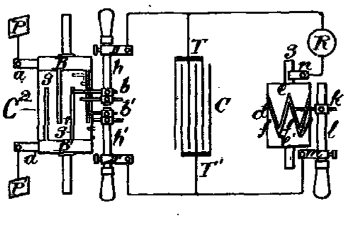
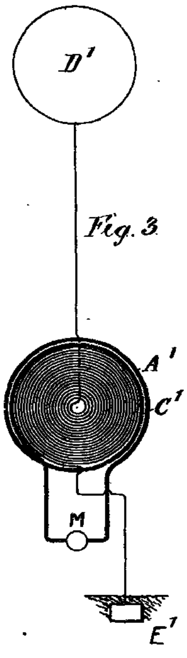


Fig. 3.



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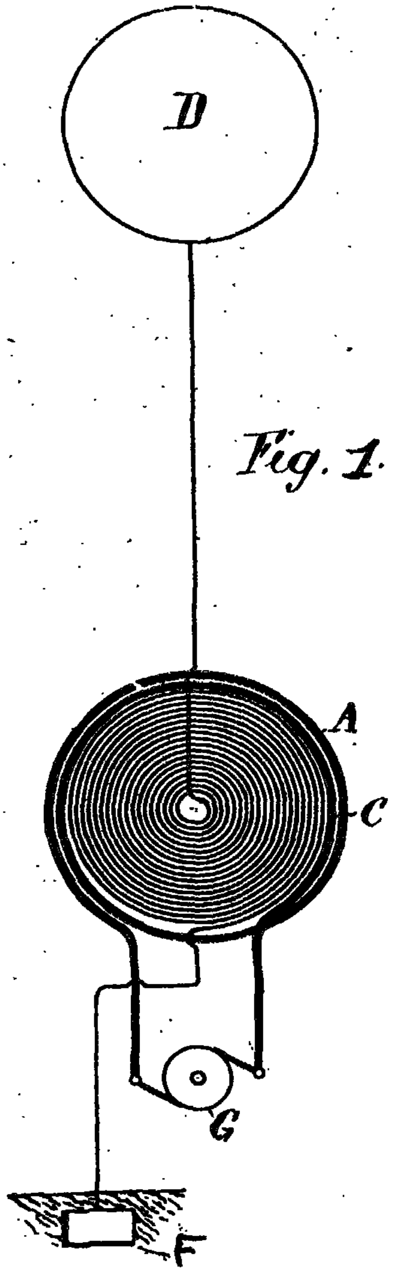
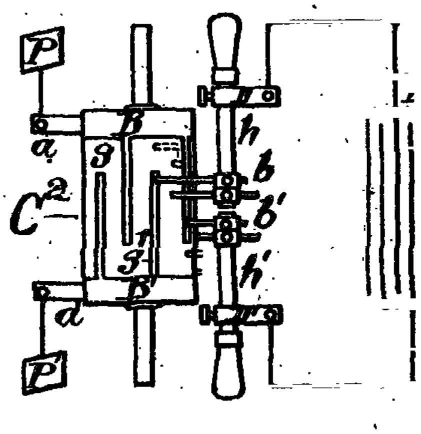


Fig. 1.



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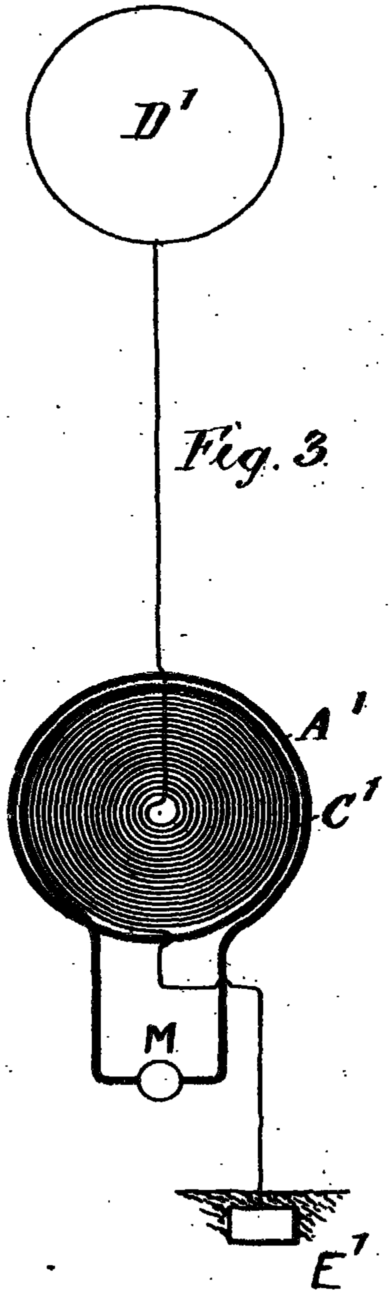

Fig. 3

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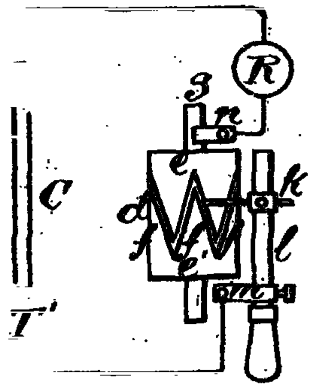

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